NUCLEAR ENERGY

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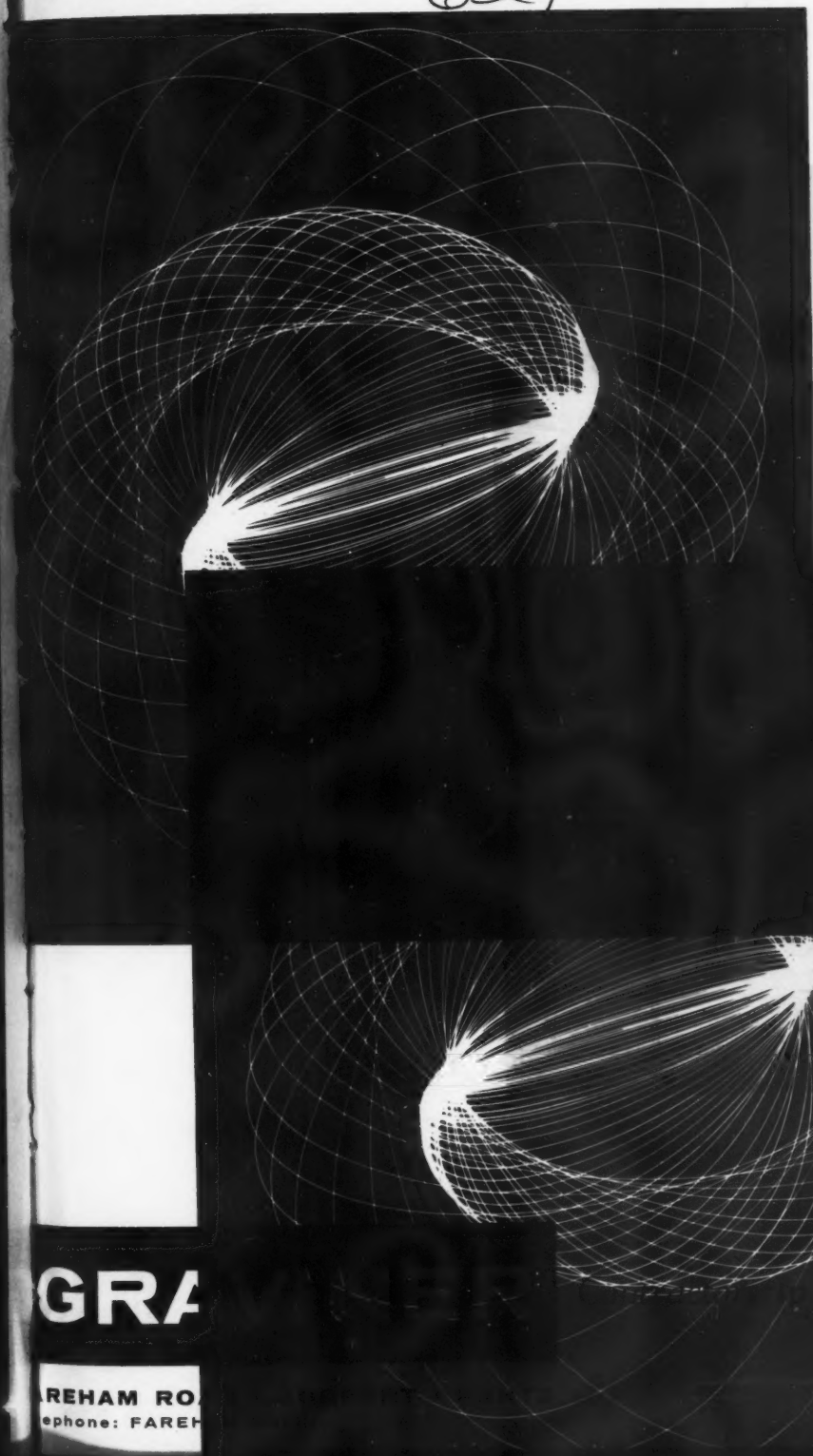

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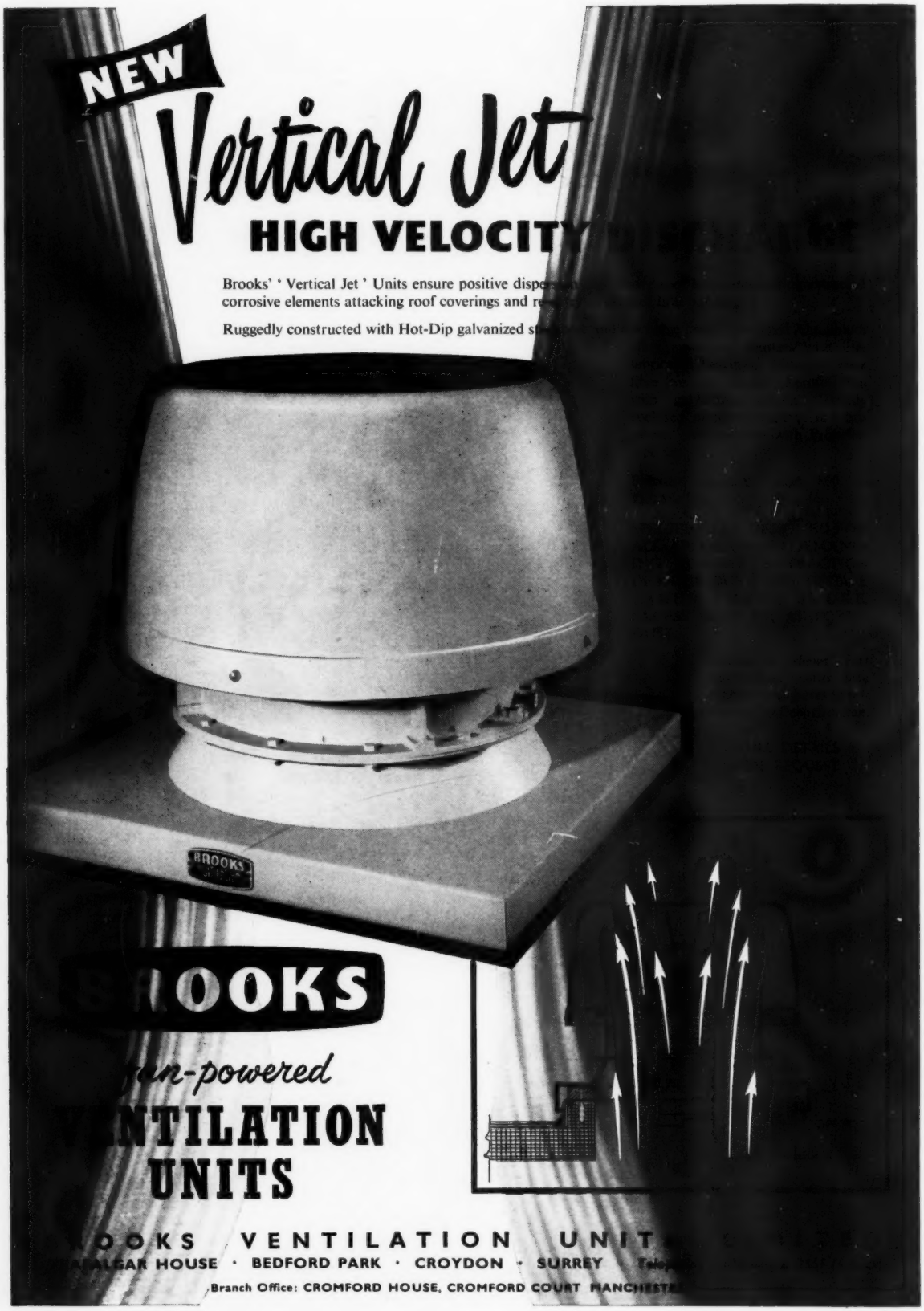
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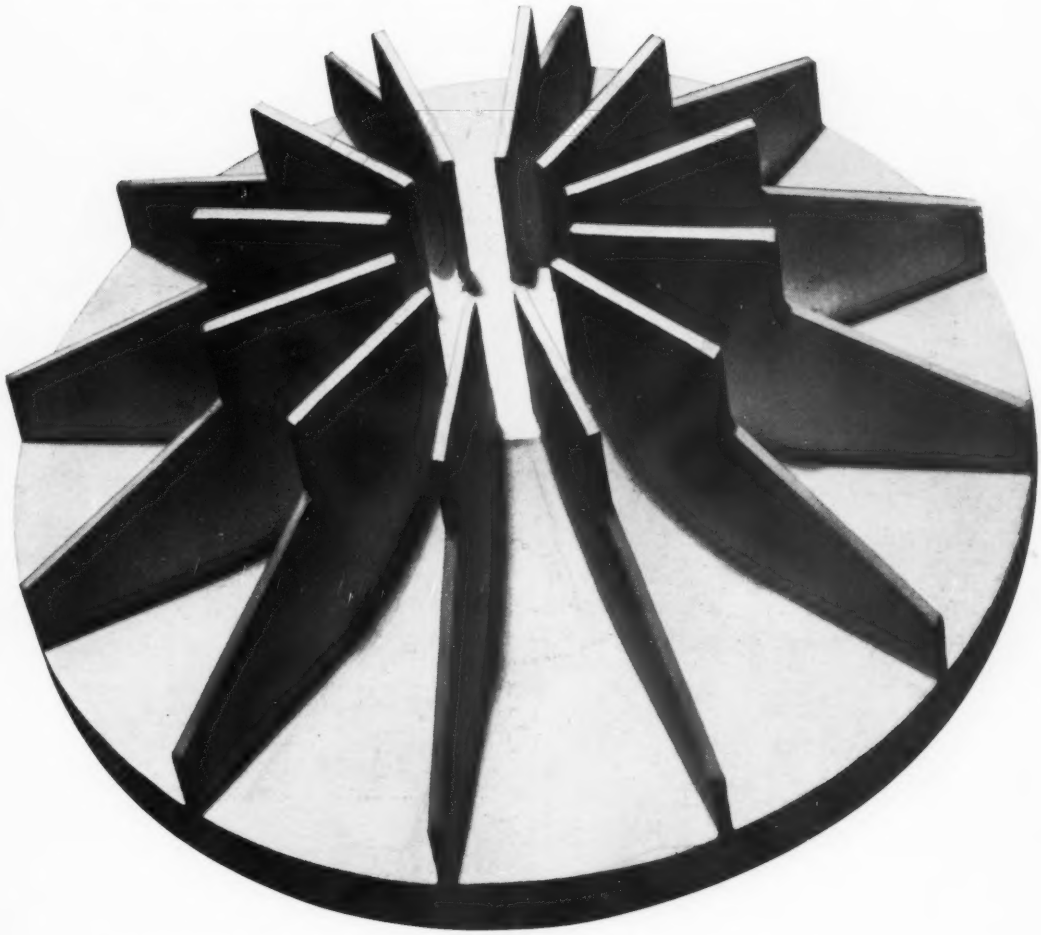

Precision Forging means exactly what it says—forging to such very fine tolerances that often no machining is required. Components such as the impeller shown here can be used in the 'as forged' condition.

This saves time; this saves money; this saves effort, H.D.A. can do it.

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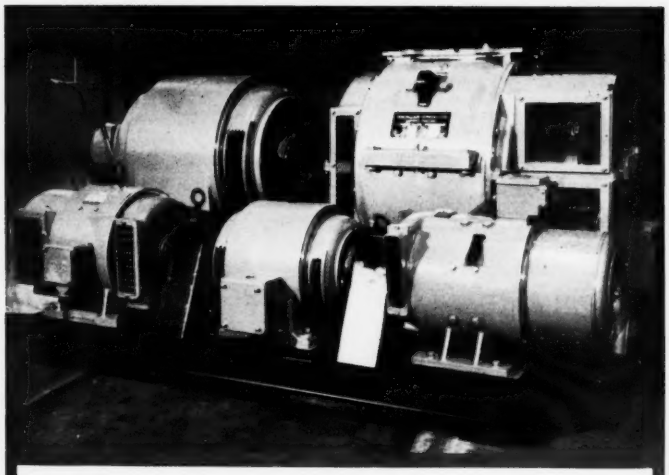
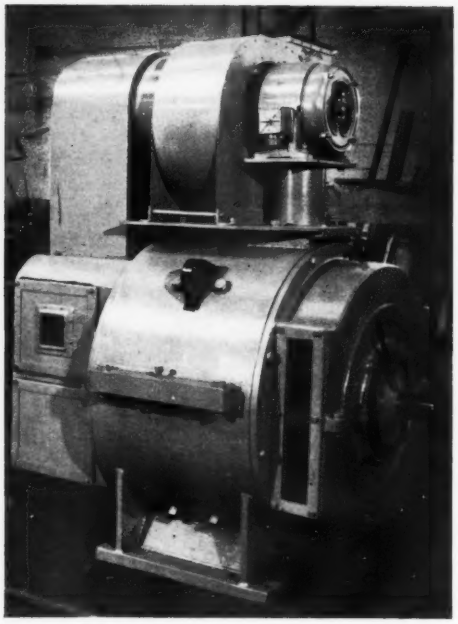
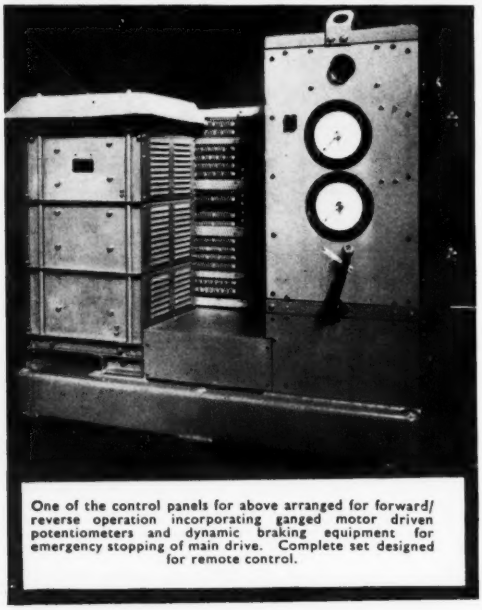




LEFT: Main motor generator set, output 0/220 volts, 200 kW max. In the foreground auxiliary set giving two D.C. voltages for drives to a calendar.

RIGHT: Work motor 240 h.p. 0/220 volts D.C., speed range 0/1500.



One of the control panels for above arranged for forward/reverse operation incorporating ganged motor driven potentiometers and dynamic braking equipment for emergency stopping of main drive. Complete set designed for remote control.

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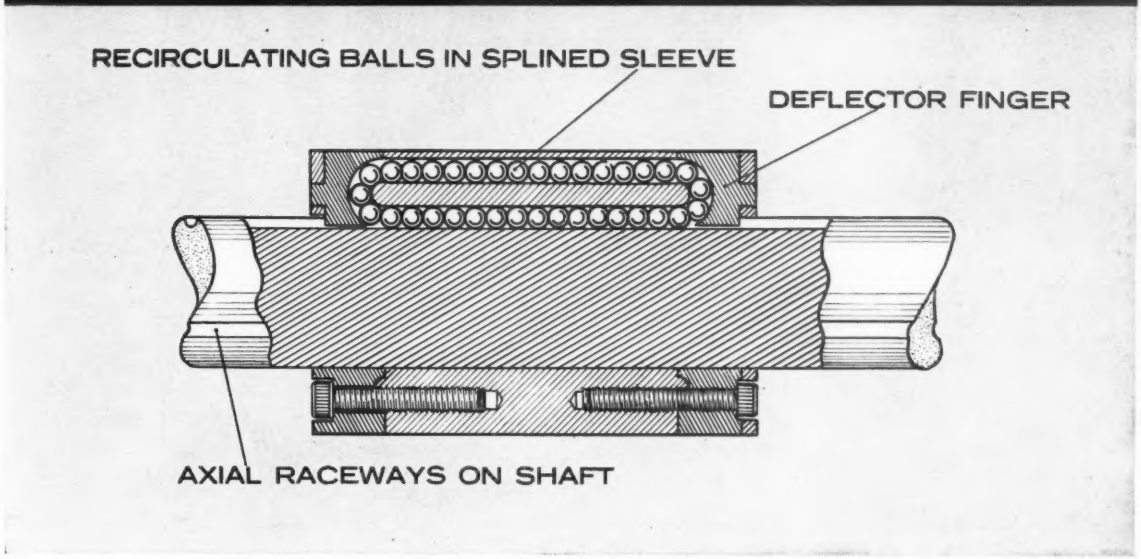

. . . ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce Beaver* ball splines. These ball splines achieve a minimum efficiency of 90% and they can operate within a temperature range of −55° C to over 450° C.

Machined and ground to the highest standards of precision, Beaver ball splines are much more efficient in operation than conventional splines. They substitute a recirculating stream of precision-ground balls, rolling along specially contoured grooves, for the solid key and keyway. This arrangement reduces friction to a minimum when the spline assembly is subjected to linear, torque and bending loads. It also gives optimum smoothness and a very fine degree of positioning accuracy. When compared to conventional spline mechanisms, Beaver ball splines require a much smaller power source; provide a predictable operating life; need much less maintenance; and give long trouble-free operation.

Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification and each unit is specially designed for its particular application. For Beaver splines can be made with angular pre-loading, with multiple circuits, and with telescopic extensions. Beaver splines have been proved as the most efficient method of minimising friction when high torsional and bending loads are imposed during linear movement in many engineering applications. They have been designed already with rated operating torque capacities of 50,000 lb/in (200,000 lb/in maximum static torque) but the maximum potential operating torque is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball screws
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For further information please write to J. B. Starky, Sales Manager, (Beaver Products Division), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

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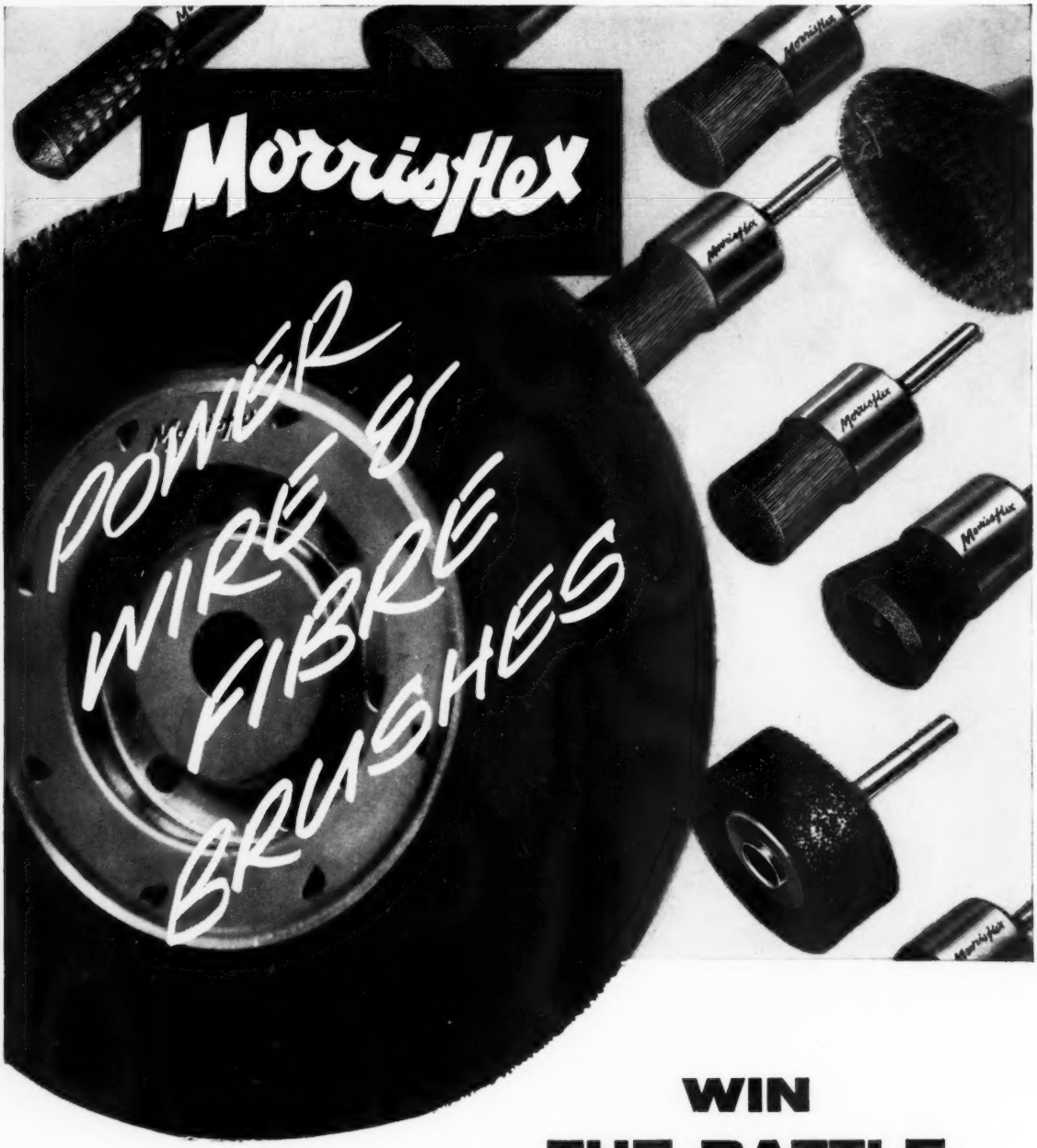

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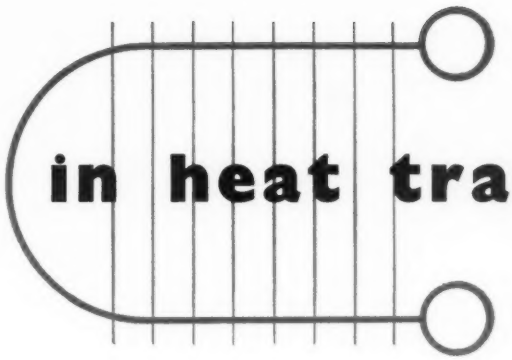

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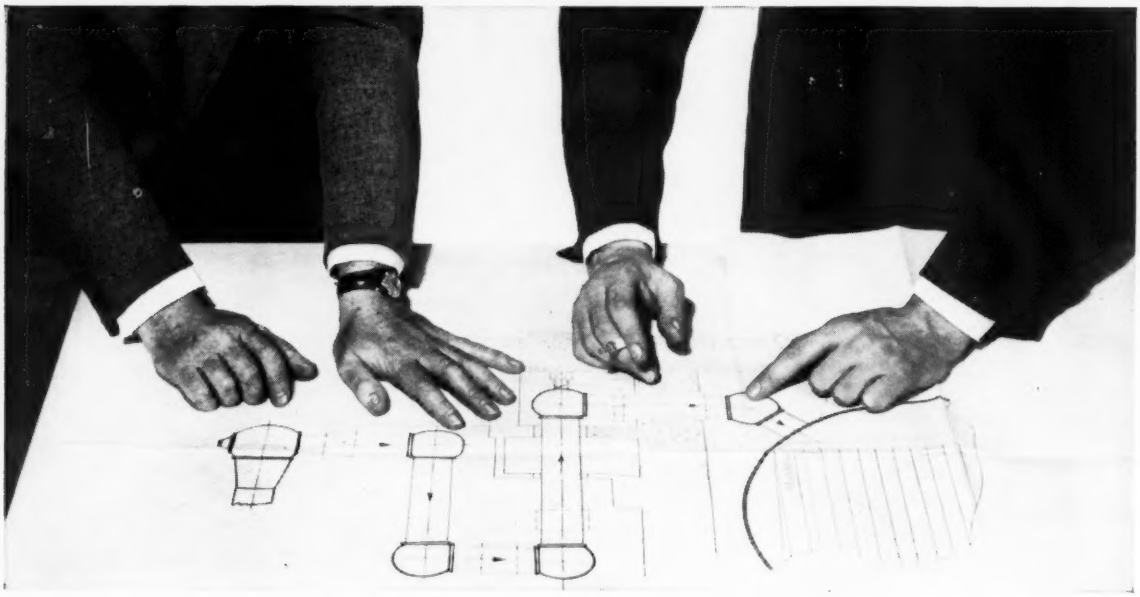
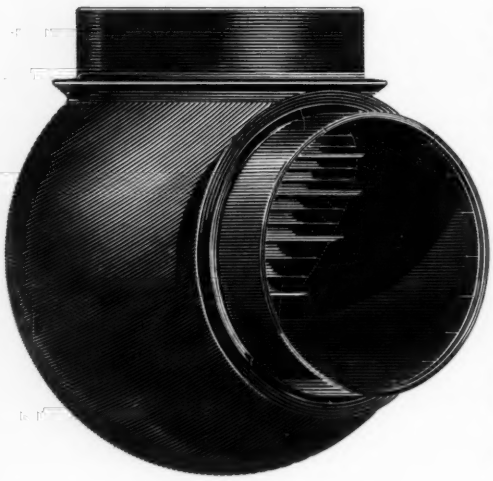


YOU COULD HEAR A PENNY DROP...



We spread out the drawings . . . an instant of surprised silence; then that gratifying sound. It is usually something like "Of course! Why didn't somebody think of that before."

Why not indeed? All we have done is to make the bends in the CO_2 pipework of an atomic reactor, spherical. Any schoolboy with G.C.E. physics knows the formula for the thickness of a pressure vessel—

$$\text{Cylindrical: } t=\frac{P.R.}{S} \qquad \text{Spherical: } t=\frac{1}{2}\frac{P.R.}{S}$$

So with a sphere you can halve the thickness of the plate. But that is only the beginning. Bonuses roll in. All welds become circular, can be made by machine and can be X-rayed easily and completely. There are no uncertainties —no stiffening webs, for instance, attached by welds which cannot be X-rayed The guide vanes are part of a lightweight duct, inside the sphere and thus unstressed by pressure.

A simple and indeed an obvious idea; but it can save large sums of money on the cost of a power station or a wind tunnel. The fact is it is not easy to see the obvious; the orthodox approach, the standard answer, get in the way. However, some of our engineers seem to be able to do it, thank goodness.

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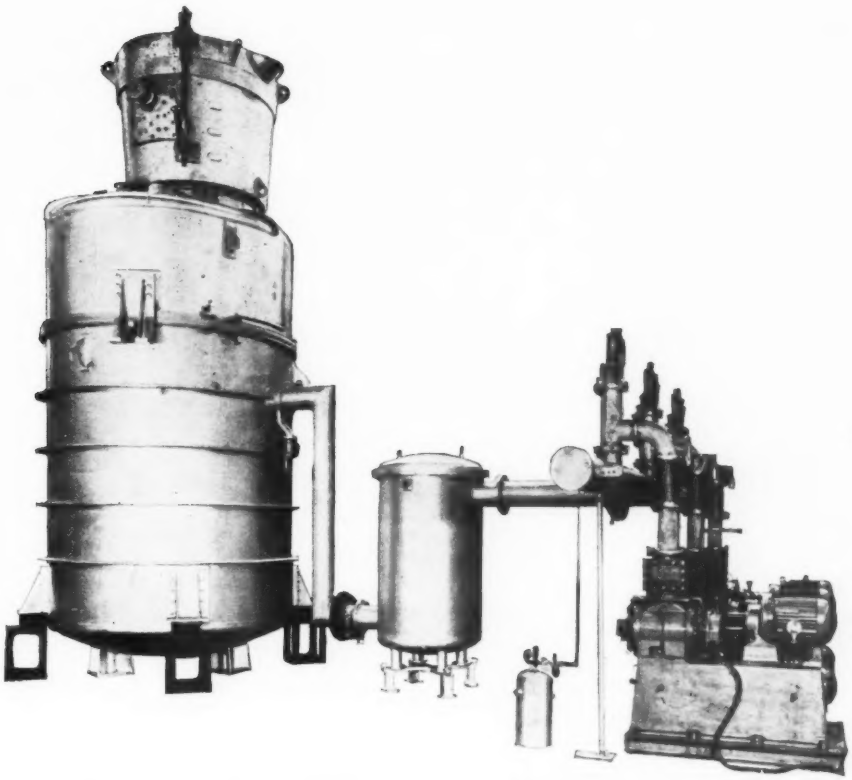

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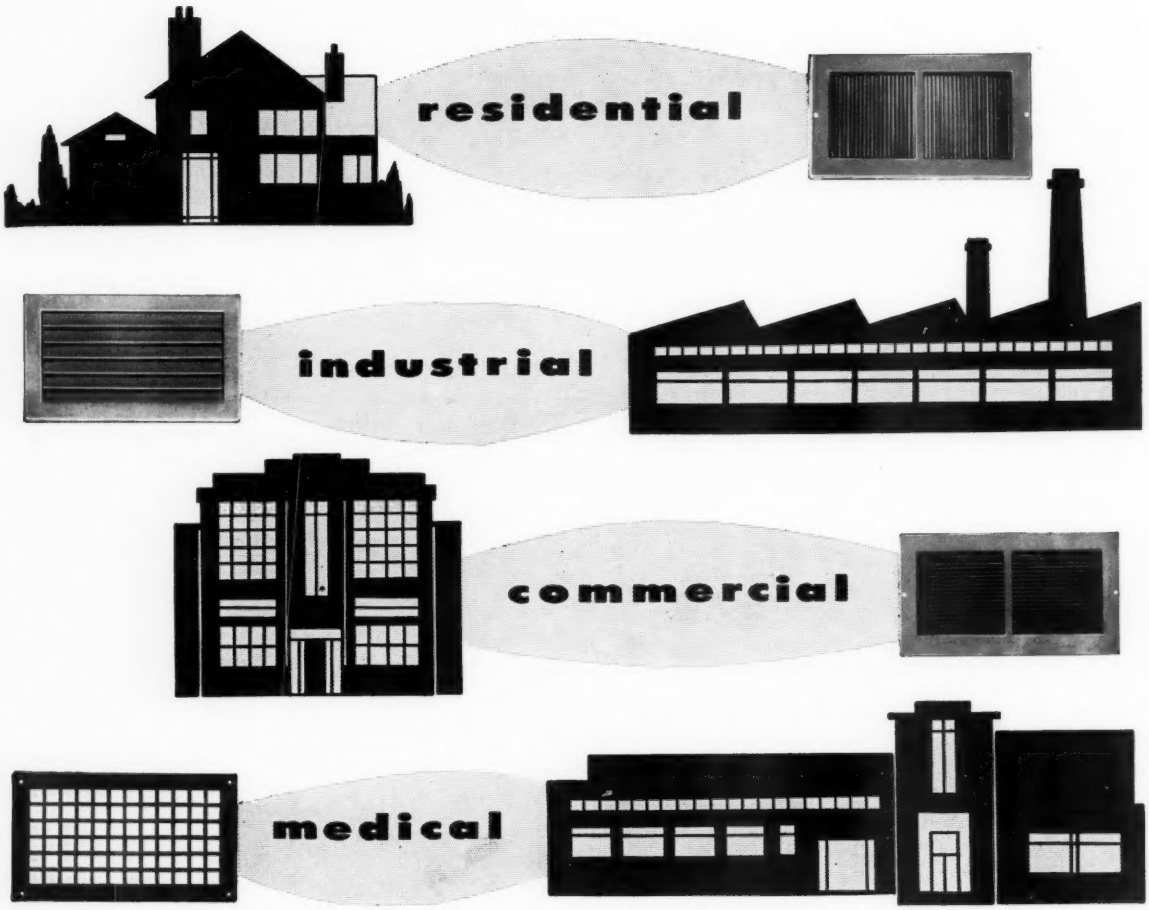

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NUCLEAR ENERGY

AUGUST, 1960

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BEHIND THE RETICENCE

NUCLEAR energy no longer hits the headlines. The public have grown accustomed to it. In fact, if the subject is mentioned publicly it is invariably with disparagement or disappointment, even sometimes with contempt. A large section of the public feel that in the past they have been hoodwinked about the prospects of nuclear energy; that the scientists, engineers and others working in the field have led them up the garden.

Most of this feeling has arisen through the ignorance of the public in relevant technical and economic matters. No matter how attractively and persuasively the facts are handed to them they very rarely really grasp the truth. This is partly due to the inability of faults of mass communications and partly due to the fact that the public are not really interested in the subject in the first place.

The scientists and engineers have, of course, themselves to blame for many of the currently held misconceptions and disillusionments. They have been unwise in some of their forecasts, and in some cases the pressure of publicity has just been too great for them. The public should perhaps be a little grateful for this instead of being disappointed and resentful, for it does at least indicate that the scientists have been making an effort to communicate with them. Unfortunately, however, having burned their fingers with the public the nuclear workers have inclined to become reticent and give an appearance of having retired into a shell of immobility and frustration. The result has been to add to the general feeling that nuclear energy is not exactly all washed up, but at least lying very dormant, and in the meantime other forms of power have stolen the limelight again.

Underneath the quiescent surface, however, there is as much activity and enthusiasm as there was in the Calder Hall days. To prove it, one has only to read through the Atomic Energy Authority's sixth annual report covering the period April 1st, 1959, to March 31st, 1960. Sir Roger Makins, chairman of the Authority, has described it as being "steady" and containing "nothing sensational." This may be, but there is much in it that reflects the genuine enthusiasm and zeal of the scientists and engineers of the Authority.

The Authority has been criticized to a great extent for sticking so resolutely to the gas-cooled graphite-moderated type of reactor concept, with only the fast breeder reactor as a possible contender for future power stations. Why does not the Authority experiment with other reactor types? the critics ask. The Authority's answer is that their funds are limited and they choose to work on a reactor type which best suits the relevant conditions, and that also there are many, many problems to be solved before the ultimate goal is reached. Some idea of the problems involved are given in the report.

We had room to mention only one side of the work of the Atomic Energy Authority, and these only briefly. But it is enough to indicate that their scientists and engineers are anything but pessimistic.

Gas bearing pumps— totally enclosed, gas lubricated—for liquids up to 700° C, without contamination . . .

. . . ANOTHER ENGINEERING ADVANCE BY BRISTOL SIDDELEY

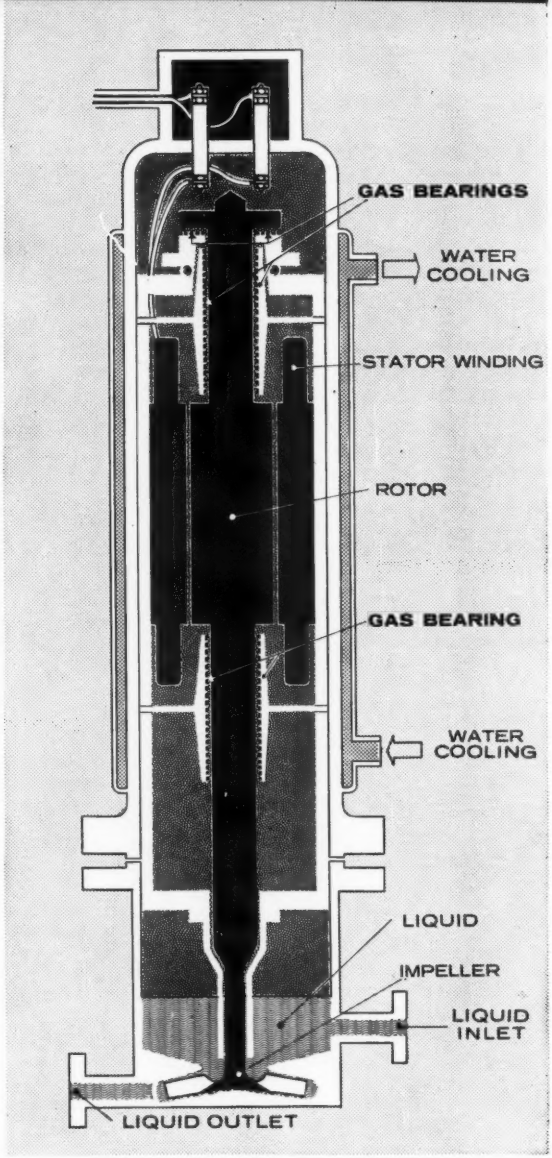
One of the largest manufacturers of motive power units in the world, Bristol Siddeley Engines Limited produce gas bearing pumps. The range covers a wide performance capacity and will pump liquids up to 700° C with a power input from fractional to 30 hp.

Bristol Siddeley gas bearing pumps have been designed specifically for systems where the contamination of liquids by lubricants or the atmosphere cannot be tolerated. Each unit, fitted with self-acting gas bearings, is totally enclosed and no seals are required between the impeller and the bearings.

Gas bearings have several great advantages over oil lubricated bearings: the load-carrying capacity increases with speed, temperature and pressure; the bearings are supported on a film of chemically pure gas contained within the system, so there is no metal-to-metal contact under operating conditions, and wear and maintenance are reduced to an absolute minimum.

Widest experience—greatest range

Bristol Siddeley gas bearings were developed originally to meet the extremely fine limits of operating purity and precision of nuclear engineering. But gas bearings have many other applications where a rotating shaft must be supported in such a way that no contamination and leakage can be allowed and where the supply of chemically pure fluids or gases is essential: in the textile, chemical engineering, pharmaceutical, food storage and processing industries, to name but a few. Bristol Siddeley produce a wider range of gas bearings than any other manufacturer and have the greatest experience in their design and application.



For further information about Bristol Siddeley gas bearing pumps and gas compressors, please write to H. J. Prince, Sales Manager, Reactor Components Division, Bristol Siddeley Engines Limited, PO Box 17 Coventry, England.

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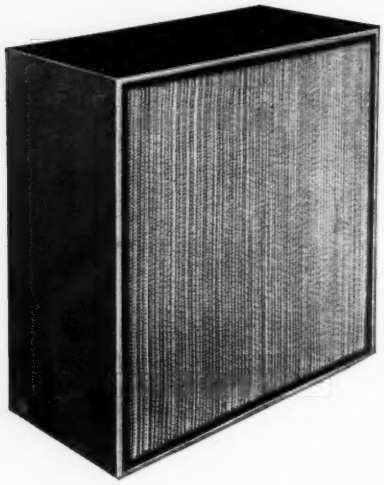

Originally developed for atomic energy work, Vokes 'Absolute' filters have also proved invaluable in biological, pharmaceutical and photographic applications — in fact wherever submicronic particles of dust and dirt can harm expensive equipment and processes. The special filter medium consisting of extremely fine asbestos fibres suspended in a grass-based paper gives a remarkable efficiency of 99.95% against particles in the 0.1 to 0.5 micron range — a figure guaranteed by subjecting every 'Absolute' filter to the methylene blue dust cloud test immediately before despatch. (B.S.S. 2831.)

Other 'Absolute' filters using an all-glass paper filter medium have *guaranteed* efficiencies as high as 99.99% — only 0.01% penetration against a methylene blue dust cloud. For further details please ask for publication HJ.

this Vokes nuclear filtration plant — the Unipak

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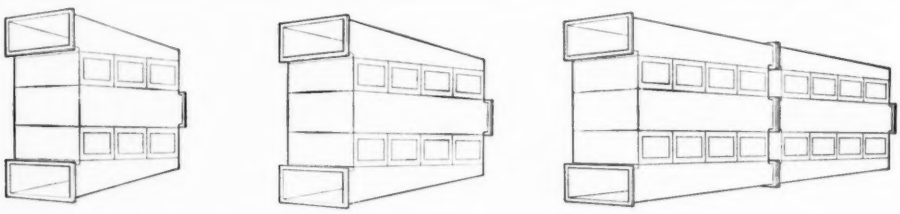

Standardized components make possible the simple construction of multiple banks to handle a wide range of air volumes. The alternative layouts available — a few of which are shown in these sketches — make the UNIPAK suitable for most requirements. Our technical engineers are always at hand, however, to advise on special installations.

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RADIATION SAFETY AND CONTROL

HAZARDS and the HEALTH PHYSICIST'S ROLE

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The health physics officer must cover such a complexity of sciences that it is difficult, and dangerous, to abbreviate a survey of this field—which is currently in a continuous flux of discoveries and policies. Nevertheless, in view of the widening industrial application and increasing medical interest, an attempt is made here to introduce some aspects of this highly specialist subject in general terms.

THE radiation hazards associated with the use of radioactive materials and machine radiation are so completely different from conventional industrial and toxic dangers with which we are all familiar, that this aspect in itself has tended to exaggerate the difficulties involved. Without specialist equipment we are all helpless to detect even the presence of a potential radiation hazard, for our natural senses give no warning. These difficulties present a number of psychological problems which colour the whole field of radiation safety and control.

An employer's liability in radiation safety is very much a matter for the legal and insurance worlds. Radiation injury and damage will naturally be a matter for the medical authorities and can only occur after extremely high exposures due to accident or negligence. The field of radiation exposures is specifically that of health physics.

Role of Health Physicists

A primary duty of the health physics officer is the prevention of unnecessary exposure to radiation hazards and the monitoring and assessment of individual exposures. The health physics organization will be responsible for the determination and measurement of existing and potential environmental hazards associated with the use of machines or substances emitting ionizing radiation. The interpretation of the data and assessment of the appropriate factors requires experience in physics, chemistry, medical, biological, electronic, meteorological and radiological techniques.

These functions are implemented by many various activities which begin even before the introduction of ionizing radiation to an establishment. The planning and design engineers should be well briefed by the health physicist on alternative procedures, and together they should evolve techniques, design shielding and develop equipment and buildings so that exposures to both radiation and contamination are reduced to a practical minimum. All unnecessary exposures and radiation hazards should be eliminated, and initial planning should allow provision for modifications that might occur as a result of experience.

Following these preliminary activities, the health physicist will be responsible for the provision of suitable safety equipment, protective devices and safeguards in preparation for the introduction of radiation work. He will also draw up codes of practice and rules of procedure with specific application to local circumstances and particular hazards.

Staff to be Trained

With the introduction of radiation hazards to an establishment personnel should be selected not only for their technical competence but with due regard to their medical history and suitability for training in radiation safety. Operators must be educated in radiation hygiene and should be trained to minimize exposure and contamination, and to use protective clothing, shields and safety equipment. A system of radiological surveys and monitoring must be maintained.

For the effective functioning of a safety service a team of competent health physics surveyors and monitors must be built up. No set of rules and regulations can produce the practical efficiency which is acquired by such a team properly trained and developed by example and functional guidance at all levels by an experienced leader.

However efficient in all these functions the individual health physics officer might be, the ultimate standard of radiation hygiene will depend both upon an integrated health physics organization and upon

ABOUT THE ARTICLE AND THE AUTHOR

With the use of radioactive materials in both research and industrial applications ever increasing the need grows for more and more scientists, engineers, technicians, teachers, lecturers and plant managers to know how to handle such materials and to control the hazards emanating from them. Where radioactive materials are used frequently, extensively and in comparatively large quantities, specialized staff responsible for maintaining accepted standards of health, safety and control have to be appointed. This article is the first in a series aimed at providing a practical background to the subject of health physics. The author, A. R. Gould, is himself well experienced in health physics, being in charge of the irradiation laboratory at the Royal Military College of Science, Shrivenham. One of the original members of Sir William Penney's original nuclear weapon development team, he was responsible for radiological surveys and safety controls at specialized field trials. Later he was the author of a radiation handbook and organized a programme of health physics within the Ministry of Supply. He joined the Royal Military College of Science staff for research into radiation effects.

every individual operator, who must apply the radiation safety precautions at all times to ensure his own safety and the safety of those around him. These factors require the health physics officer to maintain an efficient staff and constant vigilance. Success in this field will be reflected in the health physics records, which will evaluate both the extent of radiation hazards on all operations and the degree of hazard to which each individual operator is exposed while at work in the hazard area.

Two Sources of Hazard

Just what are the radiation hazards associated with the use or processing of radioactive materials? There are only two sources of radiation hazard...

(i) the radioactive materials themselves, and;
(ii) the rays emitted by these active materials.

A proportion of the atoms in materials that are radioactive disintegrate each second and the disintegrations are accompanied by the emission of radiation. There are very many complex scientific facts known about radioactive isotopes but we need only appreciate two main difficulties in working safely with them. Firstly, they cannot be distinguished from ordinary inactive materials by our senses and secondly their " activity " cannot be destroyed or neutralized.

Radioactive cobalt, for example, looks just like ordinary cobalt metal but γ rays are emitted by the material all the time. The only way in which we can detect the presence of active material is by detecting the radiation emitted with instruments. And whatever is done to the radioactive cobalt in chemical and engineering processes the emission of rays cannot be interrupted, slowed down or stopped, nor can the output of rays be increased in order to bring about earlier decay of the activity.

Psychology Counts

The practice of health physics, the management of technical personnel and the supervision of production operators are accompanied by many psychological problems that arise from these unusual features. There might be difficulty for instance in dealing with the man who finds a hazard which cannot be neutralized, sterilized or destroyed by boiling and burning inconceivable or with the individual who feels overawed by an ever-present danger that is so alien to his previous experiences. Nevertheless, these two difficulties serve to emphasize the principle axiom of radiation hygiene—" prevent and control "—as there is no " cure " or neutralizing process to render radioactive materials inert.

The rays emitted from an active material disperse in every direction and are most intense close up to the material. In fact, they obey the " inverse square law," *i.e.*, at double the distance from the source the radiation hazard is reduced by a factor of four.

Arriving at the " half-life "

As the proportion of atoms disintegrating each second is constant, it follows that the total number of atoms of the radionuclide present decay according to an exponential law. For practical convenience it is customary to quote the time taken for half the atoms of a particular nuclide to disintegrate and call it the " half-life."

A half-life may be a fraction of a second or millions of years.

Isotopes with relatively short half-lives of minutes or a few hours usually require special facilities for their production and use. They are not widely used outside specialist establishments in intensities likely to create serious radiation hazards.

For some training and research purposes it is convenient to select radioisotopes with a half-life of some two to 30 days in order to limit the period of hazard, since every 10 half-lives the activity of the material will have decayed by a factor of roughly a thousand (1,024).

Cleansing by " Decay "

When isotopes with convenient short half-lives are used it is possible to decontaminate laboratories and equipment by the " decay " technique. The laboratories and equipment are simply isolated for several half-lives. This technique is, of course, limited in application and is accompanied by the possibility of " radiochemical impurities." It should not be assumed that the activity of sources will always decay according to published data. Measurements have often shown the presence of other radioisotopes of longer half-lives which can only be detected after several half-lives of the primary source.

Chain " Decay "

Some radioactive isotopes disintegrate into " daughter elements " which are themselves radioactive. For example, the isotope of lead known as Radium D has a half-life of some 22 years and decays to a radioactive daughter Radium E—an isotope of bismuth which has a short half-life of some five days. A potential user of Radium E (which emits powerful β rays) would find that a source of Radium E would decay by about a million times in only three months. Instead of continually purchasing a succession of such sources he may decide to buy a Radium D source which will maintain a radiological equivalent amount of Radium E, *i.e.*, the activity of the " short-lived daughter " will be in equilibrium with its parent source and effectively decay with a useful half-life of some 22 years. However, such a source is much more hazardous by many orders of magnitude than one of Radium E alone, and hence the economic convenience of the long " half-life " must be assessed against the associated radiation risks.

"Body Burden" Risks

A few elements are known which remain a very short time in the body (due to their inert or non-reactive nature, *e.g.*, krypton, or due to continual isotopic exchange and/or body chemistry, *e.g.* tritium) and consequently their effective biological half-life is more significant than the physical half-life in determination of the radiological hazard as indicated by the " body-burden," ingestion, inhalation or drinking levels.

Six types of radiation may be emitted by radioactive sources depending on the isotope and on the impurities present (in the active deposits, its support or container).

The type of shielding required for any particular isotope depends upon the type of radiation emitted.

Protons, particles, positrons and electrons are all completely absorbed by convenient thicknesses (fractional inches) of perspex, glass or metals between the source and the operator. High energy photons (due to γ

emission or bremsstrahlung accompanying β emission) are, however, only exponentially absorbed by all known matter. Sources of radioisotopes which emit γ radiation require either sufficient shielding material or distance or both between them and any personnel, to reduce the photon flux to suitable values.

Most of the commonly used γ sources are conveniently shielded by lead containers during storage and are exposed for use by remote control mechanisms or long handling tongs. It is a common practice in industrial radiography to deny access to large areas around the site of exposure and so utilize the inverse square law.

Need for Labyrinth

Permanent installations of intense γ sources may require so much shielding when exposed that it is more practical to utilize concrete, in thicknesses from two to four feet, as a structural shielding container. Entrances through such shielding should be staggered through several right-angled bends in a labyrinth to minimize scattered γ radiation. However, holes for electronic, electrical and mechanical controls may be straight if they are restricted to a diameter of less than some 3 per cent. of their path length through the shielding provided this path does not point directly either at the source at one end or at areas of normal access at the other end.

Neutrons are emitted from most α sources (and some high energy γ sources) unless specially prepared. However, they are not normally present in such intensity as to create a special hazard unless intentionally prepared with certain light elements (such as beryllium, boron, oxygen or carbon) or if multi-curie sources are in use.

Materials for Shielding

Conventional shielding materials for neutron attenuation contain a high concentration of hydrogen atoms, such as water, paraffin wax polythene and other plastics. In practice, concrete or iron-concrete mixes have many structural and economic advantages as bulk shielding materials for relatively high fluxes of neutrons from subcritical assemblies, reactors, particle accelerators and other machine generators.

If the photons from γ emitting sources are of sufficient energy and pass through certain light elements they may also produce "photo-neutrons." Such sources require an assessment of shielding to attenuate both γ radiation and neutrons. High energy electrons if produced in sufficient quantities by machines such as linear accelerators may produce neutrons within a beryllium target which will also emit "Bremsstrahlung" radiation. According to circumstances shielding may be required for both neutrons and photons.

"Seeps" round Edges

Wherever shielding is required of the order of 1 ft of concrete (or 3 in. of lead) or greater, then scatter and "skyshine" must be considered around the edges of the shielding. In many circumstances the provision of sufficient shielding material to effect adequate "containment" may prove expensive. Full scale structural shielding may cost little more and at the same time provide complete protection for sources some ten to 1,000 times as strong as those originally scheduled and hence increase the scope of the facility provided.

From these basic concepts we can approach the various degrees of hazard in radiation work...

As has already been stated there are two sources of hazard associated with radiation work—(i) the radioactive material itself and (ii) the rays emitted from the material.

Little Trouble

The radiation hazard is the least problematic of the two; all that is necessary is to provide adequate shielding to prevent the spread of the rays and sufficient safeguards to keep personnel away from the source of the radiation. In most industrial and in many research applications of radiation this is the only type of hazard encountered.

While X-ray machines and particle accelerators produce large quantities of highly dangerous rays, there is no possibility of personnel being contaminated by them. No special protective clothing has to be worn in operating them, nor any special decontamination facilities provided. Personnel should however, carry suitable film badges and pocket dosimeters in order to measure the adequacy of the shielding and the measures taken to prevent the chance of exposure.

Sealed radioactive sources also present the same sort of hazard, and, of course, if they are unsealed, damaged or corroded they present the contamination hazard, too.

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It is possible for active material which is not firmly sealed in a container, such as when it is being processed or when it is being used in solution, to be spread to places where it is unwanted. Small quantities of the material can be picked up by the hand or a tool and then deposited on switches, handles, pencils, etc., causing a contamination hazard. And they will continue as a hazard until either the activity decays or the material is removed.

One of the tasks of the physics staff would be to regularly survey floors, benches, and equipment for such contamination.

Very Dangerous Hazard

Apart from the spreading of radioactive material by hand or tool, there is always the danger of it being ingested. This constitutes a very serious hazard as the most dangerous form of contamination is that deposited inside the body and the nature of this hazard should be very much impressed upon the operator.

Another serious hazard is presented by the possibility of active material being made airborne from dust, filings, swarf, evaporation or creeping of solutions, etc., or being formed in the air as smoke particles when even a small chip or fragment of active material ignites and burns. Such airborne material might well be breathed in, and deposited inside the mouth, nose and lungs. Some of it will be swallowed.

To avoid such a hazard occurring it is necessary for health physics staff to periodically check air activity at the actual site of operations and also to arrange additional checks of air activity for any operation where there might be a potential inhalation hazard.

Account for Variations

It should now be appreciated that it is possible to introduce many separate degrees of hazard with the use of radioactive materials—radiation, contamination, ingestion and inhalation—and circumstances will arise in practice in which only one of these may be the significant hazard to personnel or in which a combination of these hazards will require preventive techniques and control.

The relative hazard to operators from contamination will vary with the isotope in use depending on its half-life, specific activity, and biological half-life and on the physical nature and site of the contamination. Contamination on clothing, skin, floors, equipment or benches must be assessed with these factors in mind.

The hazard from inhalation will depend on the physiology of the elements present and on the nature of the air-borne material—its particle size distribution if particulate dust or powder, or if present as a gas or vapour absorbed or occluded on to aerosols, or as air-borne clathrates. The ingestion hazard will depend on the mode of entry into the body—whether swallowed by mouth or swallowed following inhalation, or by direct entry into the blood stream or body fluids via a wound, damaged skin or the eyes, etc. The ingestion hazard will also vary according to local circumstances of the operations involved, with the degree of radiation hygiene—regularity of hand washing, clothing changes and personal decontamination and with the incidence or absence of unofficial smoking, drinking and eating.

Assessing Control

The responsible health physicist will assess the relative hazards associated with each operation. From his assessment suitable protective measures should be taken to control the respective hazards. The health physicist will monitor the extent of each hazard and the result of routine checks shall indicate not only that permitted levels are not exceeded but that the relative hazards remain consistent with the scale of current operations. The total dosage to individual operators from all these hazards will then be assessed.

As the total exposure should be assessed as the incremental sum of each hazard present, it will be appreciated that the permitted level for each hazard must be reduced in proportion to the total number of hazards according to local circumstances. As operators aquire experience in protection and as techniques of control are developed so dosage records of personnel should indicate a consistent reduction.

In addition to hazards arising from activity there are also normal hazards to contend with. In particular any skin breaks or wounds, however trivial, may require special treatment due to the added complication of potential contamination. Instruction in radiation hygiene should point out this complication and emphasize that prevention of entry of contamination is most important.

Normal Injuries Problem

Any skin disease or skin damage increases the probability of ingestion. The health physics officer together with the medical officer should consider the seriousness of the surface damage in relation to the hazards of the operator's normal work, before advising the production supervisor on a decision to cease " active " work.

The probability of conventional industrial accidents or emergencies must be greatly reduced in all operations near to work with radioactive materials. An essential complement to a health physics organization is a complete safety and fire prevention programme. It must be recognized that a relatively minor accident or fire can produce more exposure to radiation hazard on a single occasion than may have occurred in routine work over long periods. The relatively expensive organization required to achieve a high standard of radiation safety requires a corresponding standard of protection of personnel and plant by the conventional methods of industrial hygiene and safety.

All radiation hygiene regulations and safeguards are based on what

FORTHCOMING COURSES AND EXHIBITIONS OF SPECIAL INTEREST TO THE HEALTH PHYSICIST

Sept. 5th-19th.
Practical Course in Radiation Safety and Health Physics.
City of Liverpool College of Technology.

Sept. 13th-15th.
International Conference on Instruments and Measurements.
Stockholm, Sweden.

Sept. 12th-16th.
Course on Radiological Protection.
UKAEA Isotope School, Wantage Radiation, Laboratories, Wantage, Berks.

Sept. 26th-April 28th, 1961.
Practical Course in Radiation Safety and Health Physics.
City of Liverpool College of Technology.

Feb. 6th-17th.
Practical Course in Radiation Safety and Health Physics.
City of Liverpool College of Technology.

are considered to be the maximum doses of radiation which a man can withstand without appreciable ill effects or physical damage. The most experienced body of established knowledge with wide experience in the assessment of exposure limits is the International Commission on Radiological Protection, whose recommendations are accepted throughout the world.

Minimum Dosages Lowered

The ICRP has many times lowered the maximum permissible dosages, for various reasons. The most significant are firstly radiobiological and secondly technical experience. Radiobiology, improved by genetic and somatic extrapolations from experiments and statistical investigations on large numbers of subjects has led to improved knowledge of the effects of radiation. Technical experience, which has accompanied the development of national programmes in weapon and power production, has evolved many experimental, engineering and production techniques for the processing and use of larger quantities of radioactive material with less hazard.

In short, it is now both desirable and convenient to lower exposure limits.

Contemporary instrumentation is sufficiently sensitive to measure all exposures and hazards from background levels upwards, and due to techniques of hygiene which have been developed the exposure levels of recent years are now avoidable and unnecessary.

It is inevitable that just as biological knowledge led to the major policy reversal when the ICRP abandoned the concept of "tolerance," so the technology of radiation hygiene will demonstrate that the accepted maximum permitted levels and concentrations are obsolete. When this is more widely recognized it will not be sufficient to replace the phraseology of "no appreciable injury" by the dubious "acceptable risk."

Mankind may consider that no risk, which is unnecessary and avoidable, can be acceptable in the name of employment.

International Symposium on Containment

THREE-HUNDRED engineers and scientists from 17 countries, including the United Kingdom, attended the recent symposium on nuclear containment buildings and pressure vessels organized by the department of Mechanical, Civil and Chemical Engineering of the Royal College of Science and Technology, Glasgow. Six technical sessions were held at which a total of 22 papers from authorities in the U.K. and the United States of America were presented. They covered a wide field, from research to construction and inspection.

As a preliminary to the last session which dealt with the construction, testing and inspection of containment buildings and pressure vessels, visits were made to the works of the Motherwell Bridge and Engineering Co., and to the site of the Hunterston nuclear power station.

A significant proportion of the papers dealt with the elastic analysis of thin shell structures. The problems discussed concerned linear elastic behaviour of spherical and cylindrical shells with reference to continuous and discontinuous behaviour. The effects of dead load and temperature were considered non-linear behaviour of shells, notably that due to buckling and creep, was also presented. It appeared that future pressure vessels are tending towards a cylindrical shape with hemispherical ends and a corresponding shift of the emphasis of future research work on shells may be anticipated.

Where loading can be accurately defined it is possible to obtain a reasonable correlation between theoretical and experimental stress distributions. Due to the present lack of precise knowledge concerning blast effects and missile penetration considerable work is required in this field.

Consideration was given to the way in which results of research should be presented in order that direct use of this information could be made by designers. It was suggested that those working in the field of stress analysis should maintain a much closer liaison with mathematicians in order to be sure of making the best use of available mathematical tools. Furthermore, theoretical research should be initiated, where possible, on mathematically rigorous lines. When confirmed by experiment such basic theories could then be simplified where appropriate to facilitate their translation to design data.

For greater efficiency, the operating conditions in gas-cooled reactors are progressing towards higher temperatures and pressures. Because it may not be possible to use existing cooling devices and insulation techniques efficiently at these higher temperatures, and moreover since maximum shell thicknesses would be limited by practical consideration to approximately 5 in., the responsibility for solving problems arising from these more stringent reactor operating conditions rests ultimately with the metallurgist.

Alloys Likely Answer

Slightly improved mechanical characteristics and more chemically pure steels can be produced by electric furnaces as opposed to those in use at the present time manufactured by the open hearth process. It is probable, however, that the answer lies in the use of alloys together with heat treatment. Research work in this field is already under way and further problems are being anticipated and their solutions sought—the effect of long term stress-corrosion and the mechanics and chemistry of the initiation and propagation of cracks in thick plates. Investigation in all these fields is further complicated by the effect of irradiation on steel properties and the effect of time and temperature on irradiated steels.

There was a noticeable interest shown in the use of reinforced (or prestressed) concrete as a containment medium. The main advantages to be derived from its use are economic and it is possible that construction on site, being simpler in comparison with similar steel structures, would make it an attractive proposition. Moreover, the use of concrete should eliminate a large number of thin shell problems. It was stressed, however, that concrete structures of this character would require highly stringent site control of concrete quality and emplacement.

Too Hot for Concrete

The most important disadvantages of reinforced concrete as a containment medium stems from its inability to withstand high temperature gradients and present ignorance concerning its leak tightness efficiency. Both these disadvantages could, to a very large degree, be overcome by the use of prestressing, though it is possible that reactors housed in such containments might well have to be designed to operate at less efficient conditions of temperature and pressure. The present philosophy appears to be that concrete is an attractive medium only when the contents of the pressure circuit are not retained in the containment building. Where gases are retained under pressure a continuous steel membrane is still advisable.

In the concluding session, attention was focused on the need for a design Code of Practice for nuclear pressure vessels and containment buildings. There was general support for such a code but the need for further extensive research on full scale structures and on the metallurgical aspects of the problem was stressed.

The symposium proceedings containing the papers and the discussion will be published at the end of this year.

The AGESTA

Nuclear Power/Heat Project

SWEDEN'S FIRST INDUSTRIAL REACTOR

SWEDEN'S first industrial reactor installation to come into operation will be the Agesta nuclear station situated a few kilometres south of Stockholm. Due to reach criticality during 1962, the reactor will have an initial output of 65 MW(t). Part of this will be used to operate a 10 MW back pressure turbine and 55 MW will be delivered to a district heating scheme serving over 10,000 homes in a Stockholm suburb. Later, at Stage II of the project, the output will be doubled through the addition of further heat exchangers.

The reactor will be a pressurized type with heavy water as moderator, reflector and coolant. Fuel will be uranium oxide pellets canned in Zircalloy-2.

Construction of the reactor started in 1957. At that time two separate industrial nuclear installations were planned for Sweden, the other being at Vasteras in the central part of the country. A year later, as a result of revised costing, the two projects were combined, the one at Agesta being selected as the basis of the combination.

The Swedish Atomic Energy Company (Aktiebolaget Atomenergi) is responsible for the design and construction of the reactor, the State Power Board (Kungl. Vattenfallsstyrelsen) for the ancillary parts of the reactor installation and the City of Stockholm Electricity Authority (Stockholms Stads Elektricitetsverk) for the turbine generator plant and for the district heating network. The major contractor for the reactor is ASEA (Allmanna Svenska Elektriska Aktiebolaget).

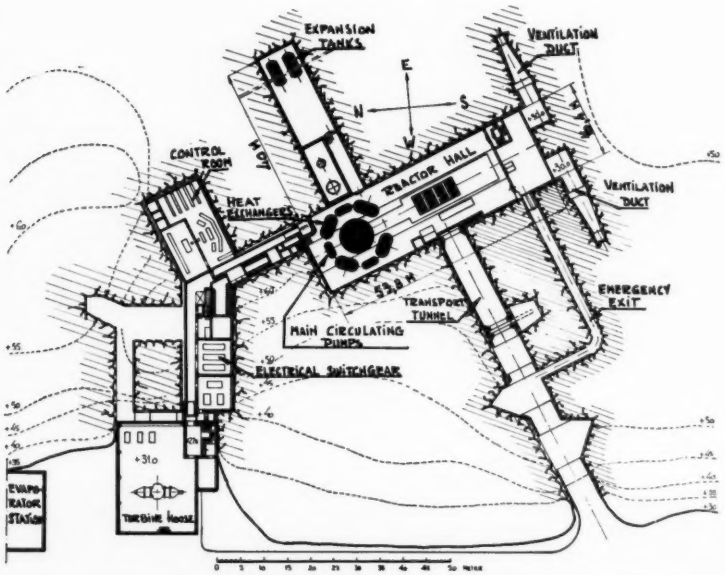
Experimental Prototype

The reactor is not intended to be economically competitive though, of course, it is hoped to receive enough revenue from heat and electricity sales to pay for some of the plant. It is intended first and foremost as a prototype both for commercially interesting district heating stations and for competitive large-scale power stations. It is also to be used to demonstrate the feasibility of operating reactors relatively close to communities with complete safety.

The reactor, coolant and auxiliary circuits, together with the station control room, are located underground, in a chamber excavated in rock. The turbine house and water purification plant are outside in the open.

It is fairly common for power plants in Sweden to be located underground. In the case of water power stations this is mainly for technical reasons. In the case of other stations it is to provide protection against possible attack in the event of war. A factor contributing to the selection of an underground site for the reactor plant was the protection afforded to the surroundings against radioactivity.

The chamber hewn out of the rock to house the reactor and coolant circuit, called the reactor hall, is 55 ft wide and 187 ft long. Maximum height is 140 ft. Minimum thickness of rock covering the hall is 45 ft. To afford further protection against the leakage of radioactivity the walls of the reactor hall are lined with steel plate.



Plan view of the nuclear heat and power station being built at Agesta, south of Stockholm

Two Ways In

There are two ways of entering the reactor hall. Either through the transport tunnel that leads directly from the rock face or through a gangway that leads from the turbine hall house. Both entrances contain double doors designed to withstand a pressure of 2.5 atmospheres. This is the pressure that would result if the primary coolant system were to be ruptured and a heat exchanger damaged, releasing the heavy water contained in the plant, together with the light water from the heat exchanger.

The reactor is situated at one end, nearest the turbine house, while in the middle are the storage wells for

irradiated fuel. A shielded fuel charge-discharge machine travels along the whole length of the hall on raised rails. The hall also contains a 120-ton travelling crane.

The control room and auxiliary plant hall, also sited in the rock, is connected to the reactor hall via decontamination, washing and changing rooms. Abutting to the rock-hewn switchgear compound is the turbine house sited outside the rock. This is built with a temporary wall to permit the building to be extended when the back pressure turbine is replaced by a pass-out turbine.

C.W. From Nearby Lake

A small lake about 1½ miles from the station is used as a source of coolant water and also as a recipient for purified waste water.

The reactor pressure vessel is a cylindrical unit 15 ft in diameter and 19 ft high fabricated from stainless steel and designed to withstand a pressure of 40 atmospheres. The top head takes the form of a cellular lid comprising two main horizontal plates separated by a grid of stiffening webs. The interspace is filled with light water to provide shielding and temperature control of the heavy masses of metal involved.

The bolted closure between the top head and the vessel is fitted with a silver gasket, and a welded toroidal ring provides a positive seal. The space between the gasket and the seal weld is monitored for leakage of the former. After the reactor has been in operation the gamma activity at the upper surface of the lid will remain low enough to enable the lid to be removed and the joint re-made without the use of remote handling tools.

The top head is pierced with 8½ in. diameter fuel ports and openings for control rod thimbles, as well as connections to the pressurizer system.

The bottom head of the reactor vessel is penetrated by four 14 in. diameter coolant inlet nozzles and four outlet nozzles of the same diameter.

The Fuel Elements

Provision is made inside the vessel for 140 fuel elements. These are made up of four sub-assemblies or bundles of 0.67 in. diameter rods of uranium oxide pellets encased in

(*Continued overleaf*)

DATA for R3/Adam—Stage I

General Parameters	
Reactor power, thermal	65 MW*
Reactor operating pressure	480 lb/sq.in. abs.
Reactor design pressure	580 lb/sq.in. abs.
Secondary steam pressure at full power	200 lb/sq.in. abs.
Secondary steam pressure at ⅓ power	300 lb/sq.in. abs.
Primary System Main Loop Temperatures	
Electric heater steam	464°F.
Pressurizer steam (gas present)	460°F.
Reactor outlet	428°F.
Fuel element outlet	426°F.
Moderator average	427°F.
Reactor inlet at full load	401°F.
Reactor inlet at ⅓ load	419°F.
Ordinary Water System Temperatures	
Lid water (constant)	417°F.
Secondary steam at full load	385°F.
Secondary steam at ⅓ load	417°F.
Flows During Operation	
Per main loop	2.02×10^6 lb/hr
Total pump flow	8.1×10^6 lb/hr
Through the 140 fuel elements	7.9×10^6 lb/hr
Through the thermal shield clearances	0.12×10^6 lb/hr
Pressures During Operation	
Pressurizer and moderator	483 lb/sq.in. abs.
Main heat exchanger inlet	478 lb/sq.in. abs.
Main heat exchanger outlet	448 lb/sq.in. abs.
Reactor inlet	491 lb/sq.in. abs.
Fuel element inlet (Bottom header)	485 lb/sq.in. abs.
Fuel element outlet pressure (Moderator)	483 lb/sq.in. abs.
Pressure Differences	
Main heat exchanger drop at full flow	30 lb/sq.in.
Main heat exchanger drop at half flow	7 lb/sq.in.
Main pump head at full flow	53 lb/sq.in.
Main pump head at half flow, open valves	14 lb/sq.in.
Main pump head at half flow, closed valves	20 lb/sq.in.
Drop over fuel elements inclusive inlet throttling—at full flow	9 lb/sq.in.
—at half flow	2 lb/sq.in.
Pressure drop in thermal shield clearances (including distribution throttling)	2 lb/sq.in.
Levels	
Normal operating water level in pressurizer from bottom	1 ft
Normal water level in electric steam generator above heater tops	1 ft
Cold water level, below reactor lid thermal shield	1 ft
During start-up heating: level in electric steam generator: above heater tops	4 in.
Main Steam Generators	
Tube diameter—outside	0.4 in.
—inside	0.315 in.
Medium straight length of the tubes	26 ft
Number of tubes	2,000
Heat surface in one unit	5,500 sq.ft
Tube plate thickness (all stainless steel)	6 in.
Inlet and outlet water plenums: divided halfsphere filled up with a steel body.	
Heavy water content in one unit	30 cu.ft
Tube sealing in the tube plate: rolling and lipseal weld.	
Plate boring quality: two-stage drilling (no broaching).	
Tube end quality: centreless grinding.	
Secondary water content/unit	13 tons
Steam chamber volume/unit	360 cu.ft
Secondary water salt content	2 p.p.m.
Make-up water salt content	1 p.p.m.
Purification flow, secondary side, per unit	2,000 lb/hr
Total height of one steam generator	33 ft
Diameter of a steam generator	5.6 ft
Fuel Elements	
Rods per element	19
Fuel rod diameter (UO_2)	0.67 in.
Canning diameter (Zircalloy-2)	0.70 in.
Canning thickness	0.028 in.
Fuel area per element	6.25 sq.in.
Water area per element	6.25 sq.in.
Minimum rod distance between cannings	0.1 in.
Total element length	12 ft
Fuel length	10 ft

*Approximately double this output is provisionally planned during Stage II.

Zircalloy–2. The overall length of each element is 12 ft, and the total effective length of UO_2 in each element 10 ft.

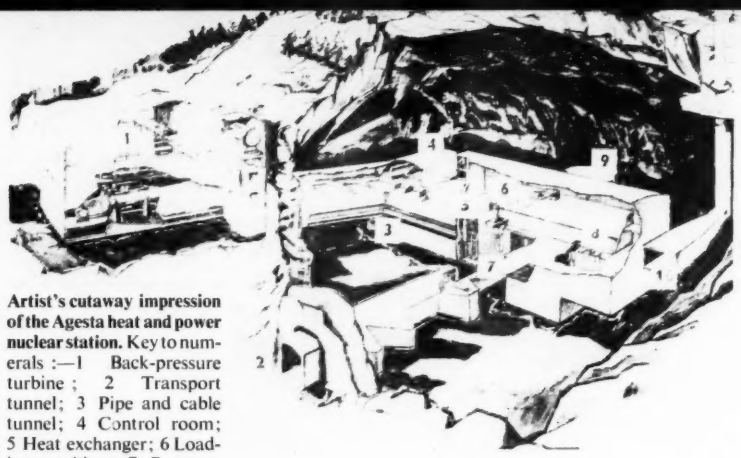
In each of the five sub-assemblies there are 19 individual rods arranged on a 0.8 in. pitch. Each fuel rod has an overall length of about 30 in. The can is capped top and bottom by fusion welded plugs of Zircalloy-2. An axial clearance is provided within the can for fission gas containment and thermal expansion of the uranium pellets.

It is envisioned that in Stage II the fuel element will be so designed that it can be divided into two parts and re-assembled with the parts reversed in order to obtain more uniform burn-up and in consequence about 33 per cent. greater average burn-up for a given geometrical buckling.

The fuel elements are removed and replaced by means of a shielded charge-discharge machine. Each of the fuel ports in the head of the reactor vessel serves four fuel element positions. To facilitate handling of the elements the machine is equipped with a rotating manipulator grab.

Reactor power will be controlled by means of regulating rods and shim rods, the latter also serving as safety or shut-down rods. Injection of boric acid as an extra safety precaution is also being considered.

The bottom and sides of the reactor are surrounded by a heavy concrete shield cooled by means of an induced air current which flows between the pressure vessel insulation and the inner surface of the concrete.



Artist's cutaway impression of the Agesta heat and power nuclear station. Key to numerals :—1 Back-pressure turbine ; 2 Transport tunnel; 3 Pipe and cable tunnel; 4 Control room; 5 Heat exchanger; 6 Loading machine; 7 Reactor; 8 Wells for fuel element; 9 Expansion tank; 10 Ventilation duct; **The reactor hall is built inside the rock and has an internal gas-tight coating of concrete and steel**

Heavy water is pumped into the reactor at a temperature of 205°C. and a pressure of 483 lb/sq.in. abs., passes up through the fuel elements to reach a temperature of 220°C. and then down to the bottom of the vessel and into the four ducts leading to the four heat exchangers. Later four more coolant loops each with a heat exchanger will be added.

It is estimated that maximum thermal loading of the fuel Stage I will be 240w/cm length of fuel and in Stage II 460w/cm. Surface heat flux will be 41 and 79w/cm² canning surface, respectively.

A burn-up of around 4,000 MWd/ton should be achieved if the fuel elements are changed as entire units and nearly 6,000 MWd/ton if the upper and lower halves of the fuel elements are interchanged after half the irradiation has been reached.

Steam Output at Stage I

With full load on the reactor the four heat exchangers used during Stage I will deliver 105 tons of saturated steam/hr at a pressure of 200 lb/sq.in. abs., and with a maximum water content of 0.5 per cent. The turbo-generator used will be a modified unit originally designed for condensing operation with a name plate rating of 15 MW. With full load on the reactor the modified unit will be capable of delivering 8 MW of electricity at 6.3 kV under normal winter conditions and 10 MW during the summer.

In Stage II of the project an oil-fired superheater may be added and the generator replaced by a pass-out turbine. The station will then be able to generate 47 MW of electricity with pure condensing operation and 36 MW(e) when supplying 70 MW of heat for the district heating. About 70 tons of heavy water and 15 tons of natural uranium in the form of UO_2 will be used.

Conditions which actuate shut down

Temperature rise in any of the fuel elements	54 F.
Reactor outlet temperature	446 F.
Blow down tank temperature	212 F.
High pressurizer pressure	510 lb/sq.in. abs.
Low pressurizer pressure	400 lb/sq.in. abs.
Low pressurizer water level (empty pressurizer)	0
High power	130 per cent.
At start up inlet temperature below	410 F.

Entrance to the transport tunnel leading into the reactor hall. The tunnel when finished will contain double doors designed to withstand a pressure of 2.5 atmospheres

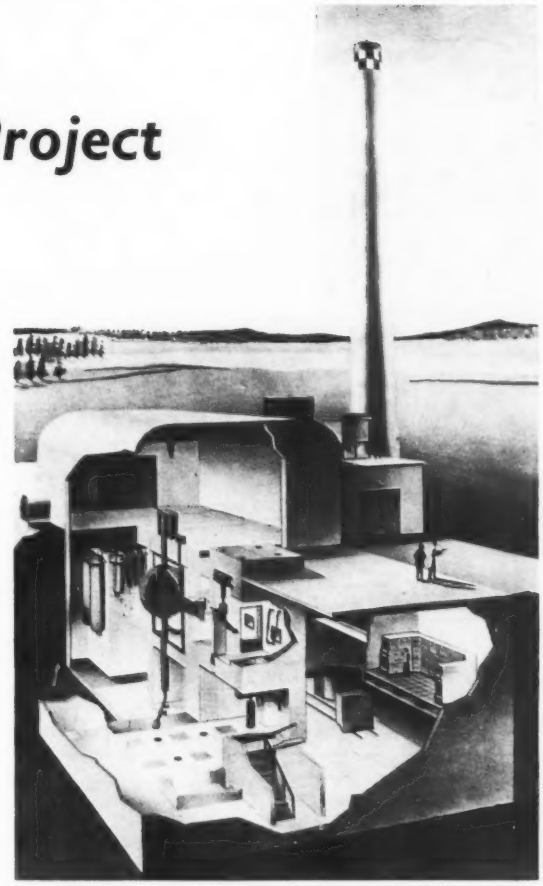
The TURRET Reactor Project

TO USE UNCLAD FUEL

LOS ALAMOS Scientific Laboratory of the University of California has recently designed and put into development a nuclear reactor, called " Turret," involving such revolutionary concepts as " unclad " fuel elements and a revolving core permitting refuelling under power. The construction of the novel type reactor will begin later this year and the reactor will go into operation in the spring of 1962.

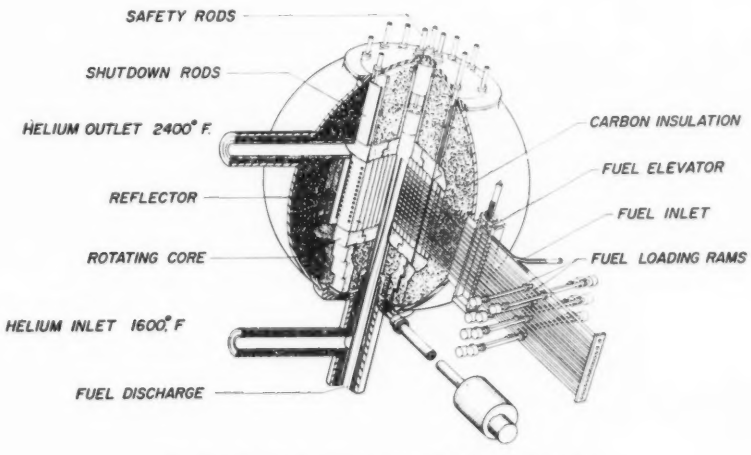
Suggested originally for electrical generation with a high temperature gas turbine, Turret has later been changed to an experimental prototype process-heat reactor operating at a power level of 3,000 kW at 2,400°F. The experiment is designed to demonstrate that this high temperature can be achieved in a nuclear reactor, paving the way for eventual synthesis of gaseous and liquid hydrocarbons from coal. The processing of these fuels, which may one day be the source of petrol for automobile engines, is a project being carried on jointly by the U.S. Atomic Energy Commission and the Bureau of Mines.

Unclad fuel elements have never been used before. Most nuclear reactors use fuel elements that are " canned "—clad in metal to keep the reaction products inside. This prevents the undesirable fission products from contaminating the reactor coolant, but lets them collect in the fuel itself. As a result, the reactor must be shut down and fuel elements must be removed for costly reprocessing at frequent intervals. In addition, cladding creates temperature limitations that prevent the reactor from running as hot as the temperatures aimed at in Turret, and allows pressures to build up that may rupture the cladding.



Artist's impression of the Turret reactor plant when completed

Turret's bare fuel elements will be made of uranium-impregnated graphite, porous enough to permit easy escape of most fission products into the coolant. The helium coolant will carry these products away and will itself be continuously purified. A gas-tight pressure shell will enclose the reactor and coolant, and a safety enclosure of steel will surround the pressure shell and some of the associated facilities, providing double protection against the escape of gas.



Line drawing to show arrangement of the Turret reactor

Fuel Costs Cut

Turret fuel elements will still have to be reprocessed, but only after a large part of their energy is spent. This means a material reduction in fuel-cycling costs. As further reduction is made possible by the unique core and fuelling system, designed to permit easy substitute of fresh fuel elements for spent ones while the reactor is in operation.

The core will be an upright cylinder of graphite, 40 in. tall and 74 in. wide, with a 12½ in. inside

diameter. The 312 radially-drilled fuel channels will each hold five hollow cylindrical slugs of fuel. Since the fuel will be inserted from the outside, the slugs at the inside ends of the channels will always be the ones most nearly spent. When one of these is ready for reprocessing, remote controls will rotate the core until the appropriate channel is in line with the fuel loading mechanism. When the loading mechanism pushes a fresh slug into the channel, all the slugs in that channel will move toward the vertical chute in the centre of the core, and the spent element will drop down the chute for reprocessing. (The name " Turret " originated from this mechanical rotating and indexing feature.)

Spent fuel elements, after a few days of decay time, will be incinerated and the remaining ash then dissolved in nitric acid. By precipitating the uranium as the peroxide, a partial fission product decontamination can be made. The peroxide precipitate is dissolved in nitric acid and used for impregnation of new graphite fuel elements.

Objects of the Project

The Turret experiment is aimed at four specific objectives. The behaviour of unclad fuel elements at high temperatures will be investigated to determine the nature of the fission products released and the degree of uranium burn-up that can be achieved. The behaviour of the coolant also will be studied with regard to the fission products deposited, the mechanism of deposition, the effects of various types of surfaces and types of flow, and removal and maintenance techniques. The experiment is expected to reveal the basic requirements and effectiveness of gas coolant purification systems and the degree to which low cost, chemically and mechanically simple fuel reprocessing or recycling methods may be applied to fuel elements like those of Turret.

The new type reactor and its supporting facility are expected to be built south-east of S Site of the Los Alamos Scientific Laboratory at a cost of approximately $3m. for construction and equipment.

NEW PORTABLE X-RAY UNIT

A Practical, Simple, and Cheap Use of Radioactive Thulium

THE Argonne National Laboratory in the United States has recently developed a small portable and inexpensive X-ray unit with great potentialities in medicine and industry. It has been tested as a diagnostic unit by Laboratory scientists.

The active component of the instrument is a tiny particle of thulium which has been made radioactive in the heavy water nuclear reactor at Argonne. Thulium is an extremely rare material which hitherto has found little practical application. The thulium is mounted in a source holder and shield equipped with a shutter mechanism in order that X-ray photographs may be made. The shutter is operated by a standard photographic cable release.

Simple and Cheap

This new development may meet the long-time need for simple, cheap, and portable equipment for making X-ray photographs. Although the entire unit weighs less than 10 lb, the radioactive thulium provides rays which are comparable in energy to a 100,000v X-ray machine. The instrument does not require an electrical power supply as does conventional X-ray equipment. In addition, it is quite inexpensive. (Exclusive of irradiation charges, the total cost of the first model was £14).

British Idea

The use of thulium as an X-ray source was first suggested by British scientists who have developed a similar but less powerful instrument. Excellent rare earth separation facilities and powerful reactors in the United States permitted development of the Argonne instrument which contains a thulium source several hundred times more powerful than the British units. This greater power makes the Argonne unit potentially useful for medical and industrial purposes.

For diagnostic purposes equipment of this type will be of greatest value in isolated locations such as Army field hospitals, naval vessels, and isolated construction projects. Industrially, it has potential use as a density determination device. It may find considerable use in the determination of levels and densities of liquids in closed systems.

Thulium was procured from the U.S. Atomic Energy Commission's Ames Laboratory at Iowa State College where Dr. Frank Spedding has pioneered in the separation of rare earth elements.

The radioactive thulium X-ray unit weighs no more than 10 lb yet produces rays which are comparable in energy to a 100,000v X-ray machine

Argonne has also supplied very strong thulium sources, made radioactive in the Materials Testing Reactor at the National Reactor Testing Station in Idaho, to the Argonne Cancer Research Hospital, Chicago, and to the Army Medical Research Laboratory at Fort Knox, Kentucky.

Pressure Vessel for the A.G.R.

A UNIQUE CONSTRUCTION

The Advanced Gas Cooled Reactor being built at Windscale and described in NUCLEAR ENERGY last month incorporates many features new to reactor design and construction. Amongst them are the novel features of the pressure vessel in which the reactor core is housed

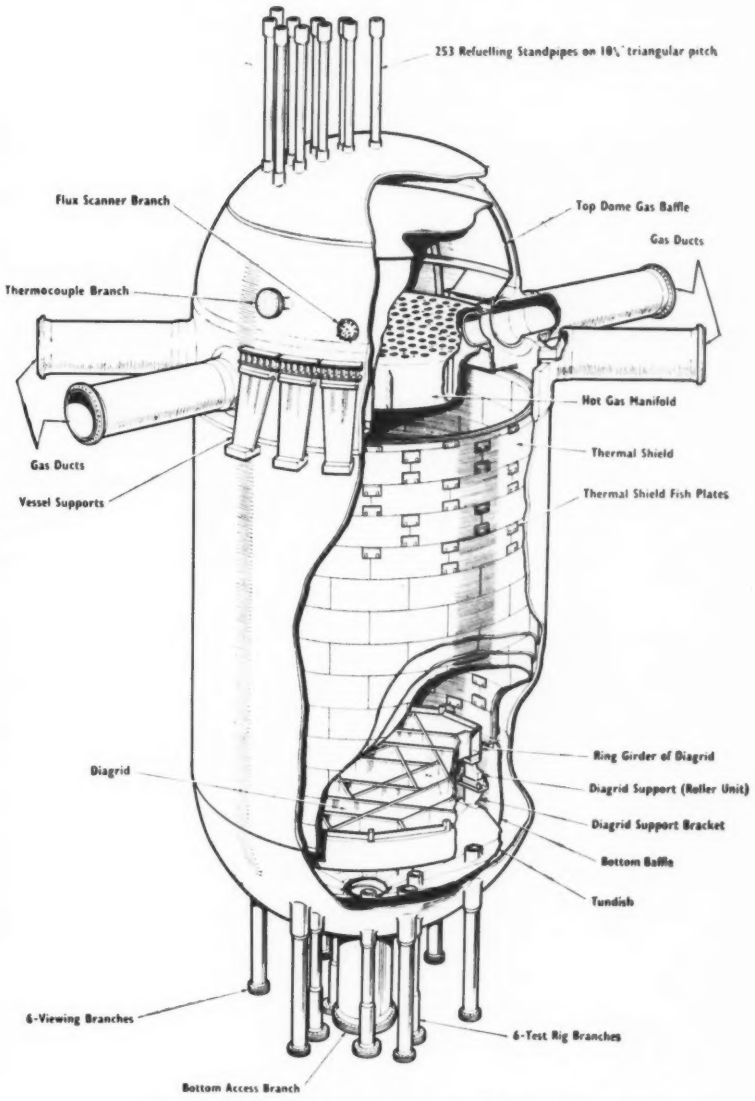
THE pressure vessel of the AGR at Windscale, though small compared with its predecessors at Calder Hall, Chapel Cross, Bradwell etc., makes up much in complication for what it lacks in size.

It comprises a vertical cylinder with hemispherical top and bottom ends and measures 21 ft 3 in. mean diameter × 53 ft 6 in. long over its ends. The working pressure for the system is 300 lb/sq.in. as compared with 100 lb/sq.in. for the larger Calder vessels so that, although smaller, it requires the use of $2\frac{7}{8}$ in. thick plates in its cylindrical portion as compared with 2 in. at Calder. The required plate thickness of the ends to simply withstand pressure would only be $1\frac{3}{4}$ in. but several special features of the vessel dictated the use of plates of up to $3\frac{7}{8}$ in. thick in the top end and up to $4\frac{3}{8}$ in. thick at certain points in the cylindrical barrel.

The welding together of these $4\frac{3}{8}$ in. plates although only a relatively small footage occurred demanded heavier welds than occurred on either Calder, Chapel Cross or Bradwell and in fact the heaviest butt welds yet occurring on a reactor vessel in this country. It should be noted, however, that a considerable footage of the same thickness has been carried out on the reactor vessel for the Latina power station, Italy.

Choice Dictated

The necessity for site welding thicknesses of plate of up to $3\frac{7}{8}$ in. dictated the use of a steel having good notch toughness qualities at the lowest temperatures likely to be encountered during construction and the steel adopted to meet this requirement was Conlo I the same as that developed for use on the pressure vessels installed at the Calder Hall plant.



Drawing to show principal features of the AGR pressure vessel

The plate was thoroughly tested before use and these tests included the taking of specimens to ensure the required degree of notch toughness as well as rigorous examination by ultrasonic methods to ensure the absence of harmful internal defects within the plate. Because of the relatively large thicknesses of plate and the relatively small radii of curvature of the finished vessel it was necessary to hot press all of the plates to shape, using full dies, at works.

In order to ensure that the mechanical properties of the plates were not impaired by this operation the whole operation was carefully monitored and carried out at a suitable " normalizing " temperature.

Although on such reactor vessels it is now relatively commonplace for a " forest " of tubes to occur on the

top end to permit the periodic replenishment of fuel it is worthy of note that on this vessel as many such standpipes occur within a 15 ft diameter circle as occur on the Bradwell vessels in a 44 ft diameter circle. This large concentration of closely pitched standpipes is necessary in order that a standpipe can occur over every fuel hole in the graphite core and permits the straight lifting in and out of strings of fuel elements.

Reinforcement Vital

Because of this large concentration it was decided that the most suitable method of reinforcing this large number of openings was by thickening up the whole of the region of end where the openings occurred to $3\frac{7}{8}$ in. Quite thin nozzles could then be used which themselves contributed little to the strength of the vessel and needed only relatively small attachment welds. The reason for this method was twofold. Firstly, the distortions which would inevitably occur if heavy welds were made between the perforated dome and the nozzles could not be tolerated. Secondly, if thick nozzles and heavy attachment welds were adopted with such close centres the welds between adjacent nozzles would be virtually touching each other and leave an insufficient membrane of "parent plate" between nozzles.

In fact the tolerances which required to be achieved on this vessel were considerably tighter than on previous vessels and in order to obtain the best possible results the following somewhat unusual step was taken. The whole top hemispherical end was completely welded together and radiographically examined before any of the holes were drilled. Using specially fabricated tubular heating elements the complete end was then stress relieved as a unit on site in order that relaxation of the stresses in the heavy butt welds could be allowed to occur before any nozzle positions were marked out.

"Hot" Box Installed

Because the hot outlet gases emerging from the core of this reactor would be at too high a temperature to permit their impingement on any part of the pressure shell it was necessary to introduce a large disc shaped collector box above the core into which all of this outlet gas flowed. This collector box or hot gas manifold was itself a pressure vessel since it required to withstand the differential of about 30 lb/sq.in. between the inlet and outlet gas pressures. Also since it was interposed between the vessel standpipes and the top of the core and had openings at every standpipe position to permit passage of fuel, it was important that it should operate at a similar temperature to the top dome in order that differential movement would not occur which would obscure the core channels from the standpipes.

For these reasons the box had to be completely internally insulated with metallic insulation. All this work had to be undertaken under rigorous standards of cleanliness and afterwards particular steps had to be taken to maintain the internal cleanliness achieved.

The hot gas from this collector box during operation of the reactor requires to pass out of the vessel through four ducts which pass concentrically inside the ducts carrying the inlet gas to the vessel, again in order that no impingement of hot gas should occur on the main pressure parts.

No "Ups and Downs"

In order to keep the duct system and boiler mountings simple it was necessary to ensure that little or no vertical movement of the vessel ducts occurred relative to the datum and to achieve this the vessel had to be supported at about the same level as that at which the ducts occurred, near to the top of the cylindrical barrel. To ensure that no radial constraint of the barrel occurred at the support point it was decided to provide a series of plate rocker supports. The top ends of these connect very close to the vessel walls and keep the bending moments there to a minimum while their bottom ends sit on a corbel projecting from the biological shield wall. Thus radial movement is free to occur and the small vertical component caused by the inclination of the rockers to the vessel is offset by connecting the rockers to the shell sufficiently above the gas duct centre lines to permit the short length of intervening shell to expand downwards by a similar amount and leave the gas ducts in virtually the same horizontal plane.

The graphite core required to be supported in the bottom of the vessel on a suitable support structure and by virtue of the triangular pitch of core holes it proved possible to devise a triangulated structure with 12 equally loaded support points around a circular ring girder. This equality of loading had not been possible on previous vessels where a square pitch of holes occur.

The loads from these 12 points were fed into the shell at the bottom dome, which was thickened up to $2\frac{1}{4}$ in. to absorb these stresses, and distributed themselves evenly into the barrel before being transferred to the external supports at the top of the barrel.

Hydraulic Tests Made

Because the load was so spread through the vessel on this design it was now feasible for the vessel to carry a head of water during testing and permitted a hydraulic test to be carried out in place of the pneumatic test which had been necessary on earlier reactor vessels.

The upper course of the barrel was thickened generally to $3\frac{1}{4}$ in. to cater for the bending stresses at the supporting points but further thickening of part of the course to $4\frac{3}{8}$ in. occurred in way of the four duct openings.

After discussion with forgemasters it proved possible on this vessel for the first time to obtain forged rings suitably curved to fit into a cylindrical shell and still permit attachment entirely by butt welding which in turn allowed full radiography of welds. These rings were produced using specially devised manufacture techniques and represent a considerable advance in pressure vessel technology.

Because of the high neutron leakage rates from the core of this reactor it was necessary to arrange for the installation of a 6 in. thick shield inside the reactor vessel. This was manufactured in triple units of 2 in. plates so overlapped that when erected the whole shield would be free standing and no direct paths would exist for neutron streaming to occur.

The pressure vessel was fabricated by Whessoe Ltd., who were responsible for the construction of the pressure vessels for the Calder Hall, Chapel Cross and Bradwell reactors. Currently they are fabricating the pressure vessels for the Latina nuclear station, Italy, which is being built by the Nuclear Power Plant Co., Ltd.

Effects of Radiation on STRUCTURAL MATERIALS

A SURVEY OF PUBLISHED WORK

by S. I. El-Sisi,
Assiut University

The different effects of irradiation on structural materials are of considerable interest to designers, engineers and others working in the nuclear energy field. The author attempts here to give a survey of research studies undertaken in this field. It is not in any way intended to be comprehensive, but merely a guide as to the most important and impressive investigations

A. Electrical Properties:

The changes that take place in the electrical properties of an irradiated material are easily detected and can be measured with precision at any temperature. In fact, measurement of such changes has been widely used for detecting irradiation effect.

Changes in electrical properties due to the introduced defects are either due to changes in the number or the mobility of the current carriers or both.

In metals measurement of the changes in electrical properties forms the basis of quantitative comparison between theory and experiment. In good metallic conductors an increase in resistivity is observed upon fast particle irradiation[1]. This resistivity increase is primarily an increase in the residual resistivity, although some changes in the thermal part of the resistivity have been observed[2].

Since the number of conduction electrons is not significantly altered due to the introduction of a very low concentration of defects, the increase in resistivity can be attributed to the scattering of these electrons by the introduced defects.

The residual (or very low temperature) resistivity of metals is very sensitive to the presence of impurities or imperfections in the crystal. The resistivity measurement must be therefore made at low temperature in order to determine the residual resistivity.

Incidentally, the irradiation itself must be made at low temperatures because the induced defects in metals are known to anneal out at such temperatures. Fig. 1 illustrates the results obtained by Cooper, Kochler and Marx[3], who irradiated 0.13 mm wire of pure Cu, Ag and Au with 12 MeV deuterons. The samples were held on a liquid helium cryostat, and the temperature was maintained in the neighbourhood of 10°K.

Alloys show very large changes in resistivity upon irradiation[4,5,6]. In this case variation comes from the change in degree of long range order and not directly from introduction of defects.

Semi-conductors present the opposite effect to that found in good conductors. Since the number of conduction electrons present is very small, very large changes in the electrical properties can be expected upon irradiation provided that the defects trap centres for current carrier. This has been found to be experimentally true[7,8,9].

Studies have also been made of the electrical properties of graphite and it has been found that such properties are very sensitive to the presence of displaced atoms. By fast irradiation the number and mobility of the carriers are altered.

B. Thermal Conductivity:

Considerable changes can be expected in the thermal conductivity of materials due to irradiation. As

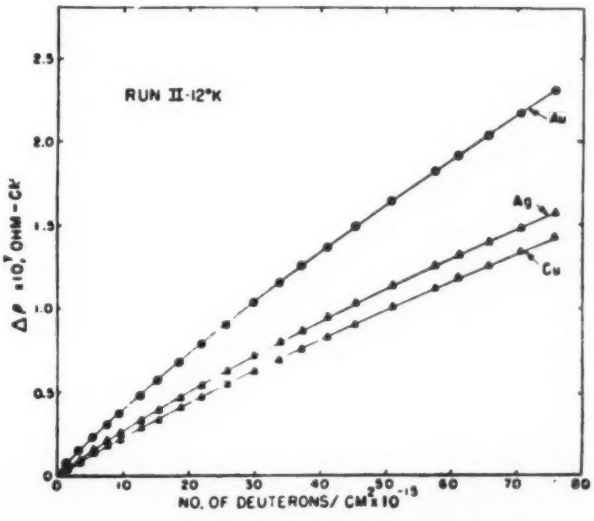


Fig. 1.—Resistivity increase as a function of integrated deuteron flux

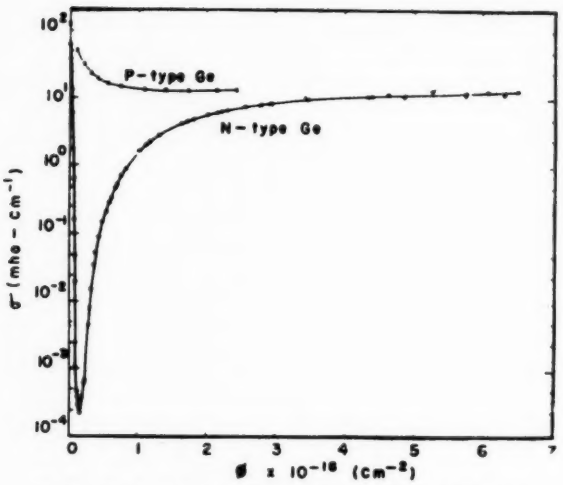


Fig. 2.—Conductivity *vs* flux density curves for an initially *p*-type and initially *n*-type sample. Irradiation by 9.6 MeV deuterons at 200°K.

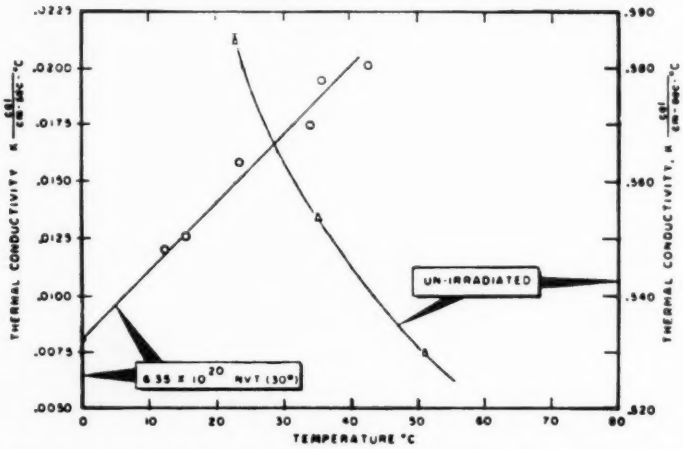


Fig. 3.—Variation of thermal conductivity with temperature for parallel cut KC graphite

there is a scattering of conduction electrons due to lattice imperfections so a scattering of thermal waves can be expected. Theoretical studies indicate that thermal conductivity is very sensitive to impurities and imperfections, specially in the temperature region where the conductivity is a maximum[10]. (Fig. 2).

Berman[11,12] has studied experimentally the low temperature thermal conductivity of irradiated quartz crystals. He found that the extra thermal resistance produced by irradiation is minimum at about 15°K, increases roughly linearly with temperature increases above 15°K, and increases more rapidly than the inverse of the temperature below 15°K. To explain the increasing resistance thermally it is necessary to assume the presence of large defects.

In diamond, no effect was observed after gamma-radiation, but a reduction in thermal conductivity was observed after neutron irradiation[13].

In graphite, the thermal conductivity was found to be maximum round about room temperature. It was expected, therefore, to find large changes in this temperature range upon irradiation [14,15] and, in fact, such expectations were verified experimentally. (Fig. 3.) Typical results.

It is clear that thermal conductivity decreases by a large factor following irradiation. In some instances, the thermal conductivity has been reduced by a factor as much as 50. Such effects are markedly reduced with temperature increase.

C. Stored Energy:

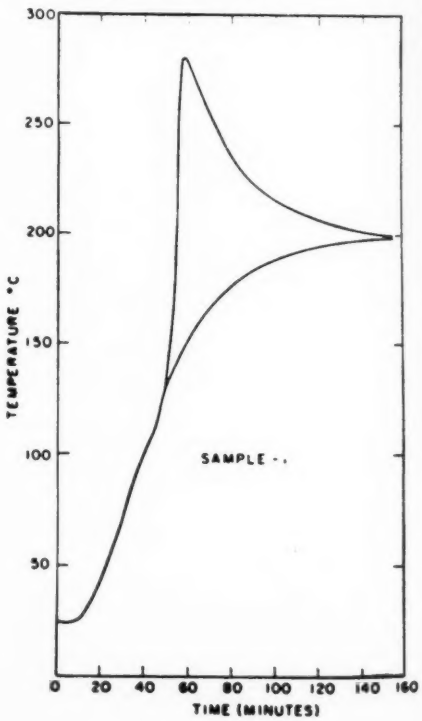
Irradiation increases the energy content of the lattice. Such an increase is referred to as the stored energy. In fact, this may be the greatest physical change accompanying the presence of irradiation defects.

If the energy of formation of the defects is known theoretically and if the total stored energy is measured, then the number of defects can be easily calculated. This has been done in the case of graphite, where the stored energy was measured as an increase in the heat of combustion[16].

This extra heat content is clearly the total energy content of the defects.

If irradiation is carried out at low temperatures so that no annealing of the defects takes place, then the above energy change is simply the total energy of formation of a given fraction of defects. If, however, aggregation has already taken place through annealing, then the corresponding stored energy is not so easily deducted. Stored energy experiments on diamond[17,18] give very similar results to those for graphite.

Fig. 4.—Time *vs* temperature plot of graphite placed in furnace held at 200°C. Upper curve, sample previously irradiated at 55°C. Lower curve, same sample after annealing



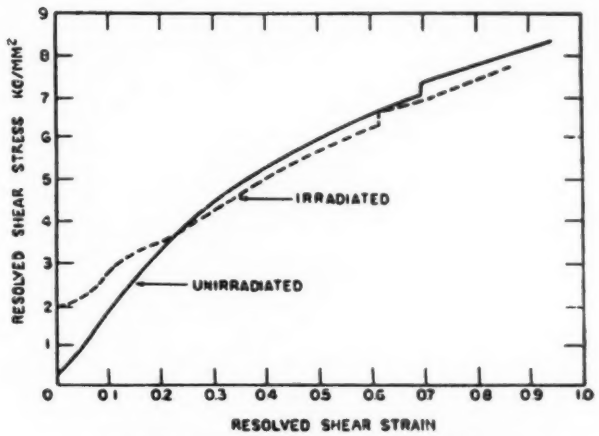


Fig. 5.—Stress-strain curves of copper crystals

The author is not aware of any other experiments in which the total stored energy has been measured in an unambiguous way. The release of stored energy over limited temperature ranges in various materials, however, has been studied[18,19].

D. Elastic Properties

The first observation of a change in elastic properties upon irradiation come from early work on graphite[15,20]. Reactor irradiation of graphite was found to produce stronger, harder and more brittle material. Young's Modulus was found to be increased by a factor of 3 upon an exposure of 10^{19} *nvt*.

Theoretical interpretations of these results is difficult because of the complicated structure of graphite.

For theoretical calculations for metals, the reader is referred to Dienes[21], who investigated the effects of vacancies and interstitials on the elastic constants of simple close-packed metallic crystals.

Detailed calculations, in which relaxation of nearest neighbours was taken into account, led to the conclusion that the presence of a small fraction of interstitials and vacancies results in large increases in the elastic moduli of copper of the order 5-7 per cent./1 per cent. of interstitial. Lattice vacancies alone were found to decrease the moduli by essentially a bulk effect. Consequently, increases in the elastic moduli are to be attributed primarily to the presence of interstitial atoms.

A rather large increase in modulus has been observed experimentally by Thompson and Holmes in copper single crystals after reactor irradiation[22,23]. These workers found that the increase in the modulus of elasticity, which could amount to 20 per cent., is not, in fact, proportional to the amount of irradiation and that no further change in modulus occurred at a very low irradiation level, namely of the order of 4×10^2 *nvt* of fast flux.

E. Effects Observable by Diffraction:

Lattice damage caused by irradiation influence the X-ray diffraction pattern of a substance. In fact, this was one of the early ways used for qualitatively detecting irradiation imperfections.

When a crystal is irradiated the characteristic sharp Bragg reflections in the X-ray diffraction pattern are generally displaced, weakened, and eventually broadened. In addition, diffuse background scattering as well as extra crystalline reflections appear. These effects are more clear in some materials than others.

F. Diffusion:

It is generally accepted that diffusion in solids takes place as a result of defects. Since fast-particle irradiation results in the presence of such defects, a close connection between diffusion and irradiation exists. For discussions of aspects in this connection, the reader is referred to Feldman and Dienes[24]. A full theoretical calculation has been carried out by Lomer[25].

G. Mechanical Properties:

Particle irradiation brings about large changes in some of the mechanical properties of metals. The increase in the elastic modulus has already been discussed and has been attributed to the pinning of dislocations by radiation induced defects. By the same argument it is expected that the critical shear stress would increase since it depends on the break-away of pinned dislocations. This is the case, and indeed this effect was observed first. Blewitt and Coltman[26] have studied the stress-strain curves of irradiated and unirradiated single crystals of copper. A typical experimental result is shown in Fig. 5.

On the basis of the shape of the stress-strain curve of the irradiated specimen, Blewitt and co-workers suggested that irradiation is somewhat similar to solid-solution hardening[27,28].

The slip characteristics of the irradiated crystal are similar to those of α-brass, and the critical shear stress *versus* bombardment curve, given in Fig. 6, is similar to those showing

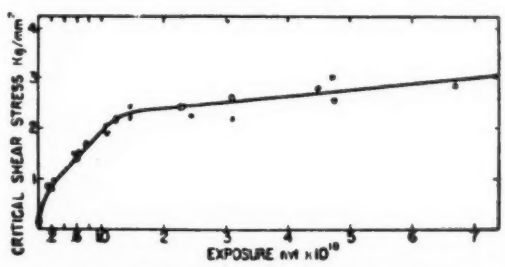


Fig. 6.—Effect of neutron irradiation on the critical shear stress of copper

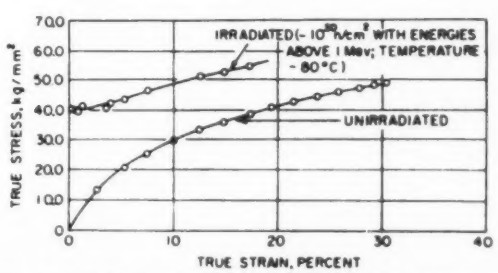


Fig. 7.—Effect of neutron irradiation on the critical shear stress of nickel

the effect of alloying (critical shear stress *versus* composition curves).

Kunz and Holden[29] obtained similar results for iron and zinc single crystal.

Further tests by MacReynolds[30] studied copper and aluminium after reactor bombardment at 80°K and found that the effects in Al annealed out before reaching room temperature, while temperatures of about 300°C. were required before the increase in the critical shear stress of copper annealed out, in agreement with the observations of Blewitt and Coltman.

The values of the critical shear stress obtained in these experiments are much larger than those obtainable by alloying.

In some metals, the whole stress-strain curve is appreciably altered by irradiation. A typical example is the curve for nickel shown in Fig. 7 taken from the work of Bruch, McHugh and Hockenbury[31].

Irradiation also affects the brittle-to-ductile transition temperature in those metals that exhibit a brittle behaviour below a certain temperature and a ductile behaviour above this temperature. Meyer[32] studied in some details this effect in mild steel using 18-6 MeV deuterons for irradiation.

Fig. 8 illustrates the results obtained in impact tests before and after irradiation with an average total exposure of 6.7×10^{17} particles/cm. This irradiation increased the transition temperature from −1°C. to about 8°C. Such embrittlement appears to be characteristic of body.

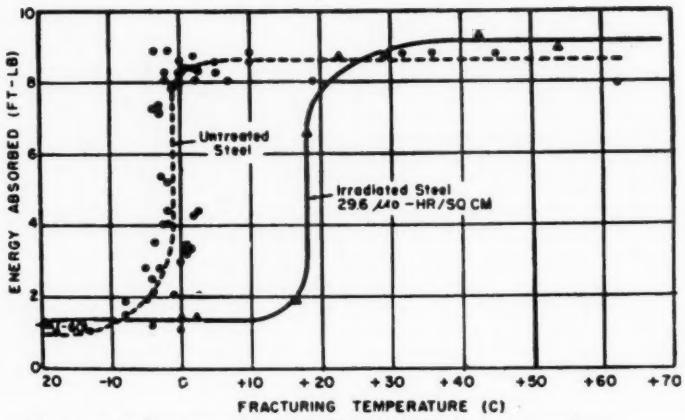


Fig. 8.—Transition curve for untreated and irradiated impact specimens

References

[1]Broom, T., " Lattice Defects and the Electrical Resistivity of Metals." *Phil-Mag. Suppl.*, 3,26 (1954).

[2]Bowen, D., and Rodebach, G. W., " The Influence of Cold Work and Radiation Damage on the Debye Temperature of Copper." *Acta Met.* 1,649 (1953).

[3]Cooper, H. G., Kochler, J. S., and Marx, J. W., " Irradiation Effects in Cu, Ag, and Au Near 10°K." *Phy. Rev.* 97,599 (1955).

[4]Siegel, S., " Effect of Neutron Bombardment on Order in the Alloy Cu-Au." *Phy. Rev.*, 75,1823 (1949).

[5]Cook, L. G., and Cushing, R. L., " The Effect of Neutron Irradiation in the NRX Reactor on the Order-disorder Alloy Cu-Au." *Acta Met.* 1,539 (1953), 1,549 (1953).

[6]Aronium, L. R., " Radiation Damage Effects on Order-disorder in Nickel-Manganese Alloys." *J.Appr.Phys.*, 24,229 (1953).

[7]Lark-Horovitz, K., " Nuclear Bombarded Semi-conductors." Reading conference on semi-conducting materials, Butterworth's Scientific Publications, London 1951, pp. 47-48.

[8]Cleland, J. W., Crawford, J. H., Lark-Horovitz, K., Pigg, J. C., and Young, F. W., " The Effect of Fast Neutron Bombardment on the Electrical Properties of Germanium." *Phy. Rev.*, 83,312 (1951).

[9]Fan, H. Y., and Lark-Horovitz, K., " Fast Particle Irradiation of Germanium Semi-conductors." *The Physical Society*, London 1955, pp. 232-245.

[10]Berman, R., " The Thermal Conductivity of Dielectric Solids at Low Temperature." *Phil-Mag. Suppl.* 2 (1956).

[11]Berman, R., " Effect of Neutron Irradiation on the Thermal Conductivity of Quartz Crystal at Low Temperature." *Nature*, 166,864 (1956).

[12]Berman, R., " The Thermal Conductivities of Some Dielectric Solids at Low Temperatures." *Proc. Roy. Soc.* (London), A208,108 (1951).

[13]Berman, R., Foster, K. L., and Rosenberg, H. M., " The Thermal Conductivity of Irradiated Dielectric Crystals at Low Temperatures." *The Physical Society* (London) 1955, pp. 321-327.

[14]Berman, R., " The Thermal Conductivity of Some Polycrystalline Solids at Low Temperatures." *Proc. Phys. Soc.*, London A65, 1929 (1952).

[15]Woods, W. K., " Irradiation Damage to Artificial Graphite." United Nations, 1956, Vol. 7, p. 455 (paper 746).

[16]Prosen, E. J., and Rossini, F. R., " Some Experimental Data on the Heats of Combustion of Benzoic Acid and Carbon (graphite)." *J. Res. Natl. Bur. Standards*, 33,439 (1944) R.P.1619.

[17]Primak, W., Fuchs, L. H., and Day, P. P., " Radiation Damage in Diamond and Silicon Carbide." *Phys. Rev.*, 103,1184 (1956).

[18]Kobayaski, K., " Annealing of Radiation Effects on Sodium Chloride Irradiated with High Energy Protons." *Phys. Rev.*, 102,348 (1956).

[19]Blewitt, T. H., Coltman, R. R., Noggle, T. S., and Holmes, D. K., " Very Low Temperature Irradiation of Metals at 35°K." *Bull. Am. Phys. Soc.* II, 1,130 (1956).

[20]Mayer, G., Perio, P., Gigon, J., and Tournarie, M., " Modifications Produced in Non-metallic Materials by Radiation, and the Thermal Healing of these Effects." United Nations, 1956 Vol. 7, p.674 (paper 362).

[21]Dienes, G. J., " A Theoretical Estimate of the Effect of Radiation on Elastic Constants of Simple Metals." *Phys. Rev.*, 86, 228 (1952).

[22]Thompson, D. O., and Holmes, D. K., " Effect of Neutron Irradiation upon the Young's Modulus and Internal Friction of Copper Single Crystals." *J. Appl. Phys.*, 27,713 (1956).

[23]Thompson, D. O., Holmes, D. K., and Blewitt, T. H., " Neutron Irradiation Effects upon Young's Modulus and Internal Friction of Copper." *J. Appl. Phys.*, 26,1188 (1955).

[24]Feldman, M. H., and Dienes, G. J., " Silver Self-diffusion in a Radiation Field." UAEC Document NAA-SR-Memo 22 (1951).

[25]Lomer, W. M., " Diffusion Coefficients of Copper under Fast Neutron Irradiation." AERE Report 1540 (1954).

[26]Blewitt, T. H., and Coltman, R. R., " The Effect of the Pile Irradiation on the Stress-strain Curve of Copper." *Phys. Rev.* 82,769 (1951) (A).

[27]Jamison, R. E., and Blewitt, T. H., " Some Deformation Characteristics of Reactor Irradiated Copper Single Crystal at 78°K. and 300°K." *Phys. Rev.* 91,237 (1953) (A).

[28]Jamison, R. E., and Blewitt, T. H., " Slip Lines in Pile Irradiated Copper Single Crystals." *Phys. Rev.*, 86,641 (1952) (A).

[29]Kunz, F. W., and Holden, A. N., " The Effect of Short Time Moderate Flux Neutron Irradiation on the Mechanical Properties of Some Metals." *Acta Met.*, 2,816 (1954).

[30]McReynolds, A. W., Auguslyniak, W., McKeown and Rosenblatt, D. B., " Neutron Irradiation Effects in Cu and Al at 80°K." *Phys. Rev.* 98,418 (1955).

[31]Bruch, McHugh and Hockenbury, " Variations in Radiation Damage to Metals." *J. Metals*, 8,1362 (1956).

[32]Meyer, R. A., " Influence of Deuteron Bombardment and Strain Hardening on Notch Sensitivity of Mild Steel." *J. Appl. Phys.*, 25,1369 (1954).

The Organic and Alpha Laboratories

RADIOCHEMICAL CENTRE, AMERSHAM

TO enable the Atomic Energy Authority's Radiochemical Centre at Amersham to meet the ever-increasing demand for isotopes, two new production laboratories were recently opened. One of them has been designed specifically for making labelled compounds with carbon-14 and tritium and the other for the handling of radium and other natural radioelements.

The new buildings cost £278,000 and they were constructed in 83 weeks. They have a floor space of 30,000 sq.ft. They were designed by E. D. Jefferis Mathews, OBE, FRIBA, and built for the UKAEA by Jesse Mead, Ltd., of Chesham.

Separate Layouts

The two buildings serve distinct technical purposes, which have dictated quite different layouts; but they are similar structurally in having precast concrete frames with aluminium curtain walling. The two units are joined by a central plant room at first floor level which provides common services, and each is planned for future extension. Both are artificially ventilated by air ducts carried within the roof and floor spaces, and both have separate drainage systems dealing with radioactive effluent.

For C-14 and Tritium

The Organic laboratory which has an area of 15,000 sq.ft, is designed for chemical and biological work with C-14 and tritium. Both these isotopes are of relatively low toxicity and neither of them emits penetrating (gamma) radiation. Accordingly no heavy screening is necessary and the laboratories are on two floors and their facilities are similar to those of conventional organic chemical laboratories. The four main laboratories run north and south on either side of a courtyard, with offices grouped on the north side. The instrument rooms are on the south side, which is without windows so as to reduce temperature variations within. The fume hoods, which have been specially designed to accommodate the glass vacuum systems in which most C-14 and tritium syntheses are performed, are an important feature of the equipment.

The technical requirements in the Alpha laboratory are quite different from those in the Organic. It is designed for work with radium and other naturally-occurring radioelements, which are not only highly toxic, and therefore need the most rigorous containment, but may also emit most penetrating gamma radiations and so require heavy screening and remote handling equipment.

Four "Hot" Benches

The laboratory has therefore been planned on one floor only and its centrepiece is a block of four "hot benches," which are screened with 3 ft to 4 ft of concrete and up to 10 in. of lead. Each bench is 50 ft long and accommodates a system of inter-connecting reaction boxes. The work is handled by mechanical manipulators and is viewed through lead glass windows, up to 18 in. thick. A remotely-controlled electric railway runs within the boxes so that active materials can be conveyed quickly and safely from one to another. Particular attention has been paid to corrosion and ease of decontamination: the boxes are

The Radiochemical Centre is an establishment of the Research Group of the Atomic Energy Authority. Until March, 1959, the arrangements for the production and marketing of radioisotopes had been shared between the Centre and the Isotope Division of the AERE, Harwell. The scope of the Centre was then widened to form a single comprehensive organization with headquarters and principal laboratories at Amersham. Research into the fundamental properties of radioisotopes and their applications is carried on by the Isotope Research Division at Wantage. During the first year of its reorganization the Centre dealt with some 35,000 consignments of radioisotopes whose total value exceeded £1m. The Centre, which is run on commercial lines, employs about 300 people

constructed of glass-reinforced polyester resin and are coated with a strippable lacquer.

Other facilities in this building include a "frogmen's room," in which radioactively contaminated equipment can be serviced by operators working in pressurized air suits. There are associated control and decontamination rooms. There are also two laboratories for work with pure alpha-emitters such as polonium. All reaction boxes in the Alpha laboratory are connected through filters to a separate exhaust system which discharges to air at 75 ft above ground.

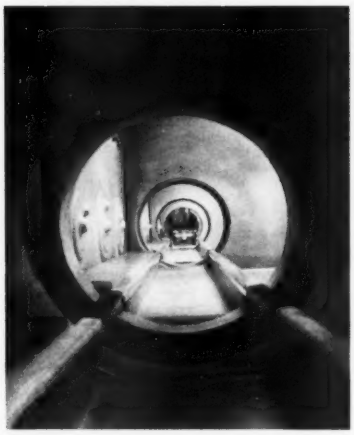
Overall Output

The purpose of the organic department to which the new organic laboratories are attached is to provide a liberal supply of labelled compounds for the many research workers who use radioactive tracer methods in science, medicine and industry. Work with C-14 was started at Amersham in 1948 using imported materials. The problem has been to derive from one simple form of C-14—which can be obtained only as carbon dioxide or carbonate—the widest possible range of labelled organic chemicals. The number of compounds made available has increased rapidly with the years: it was five in 1949, 27 in 1951, 110 in 1954, and 120 in 1956. At present, about 230 C-14 compounds are listed and most of them can be supplied from stock. There is also an ample supply of C-14 which is now made in the Authority's reactors. New compounds which have been added recently include cortisone, cholesterol, E.D.T.A., decamethonium bromide, and nicotinic acid. The specific activity and purity of all products has been progressively improved.

Uses for Tritium

Tritium, though strictly a tracer for hydrogen, has many applications as a molecular label and its cheapness and low toxicity make it a promising isotope for biological researches. Preparation of tritium compounds started at Amersham in 1958/59. This has progressed rapidly because tritium labelling can often be accomplished more directly, as by catalytic exchange, than with C-14. About 50 compounds are now available, including amino acids, sex hormones, cortisone, folic acid, pyridoxine and histamine. A particularly important item is thymidine which can be used to label the nucleic acids in blood cells and to mark individual chromosomes.

The new laboratories are concerned mainly with C-14 and tritium compounds, but elsewhere the department continues to make important radioactive pharmaceutical products. Human serum albumin labelled with iodine-131 is available routinely for determination of blood volumes and flow in human patients, and for metabolic studies. Vitamin B12 labelled with cobalt-58 is often used diagnostically in cases of pernicious anaemia, and also as an analytical control during the manufacture of this vitamin.



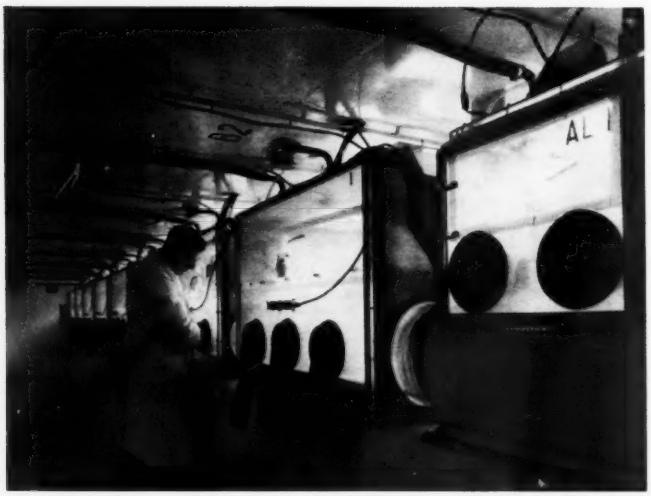
The cells in the Alpha laboratory are connected by a remotely controlled railway. Part of the track is shown in this illustration

Natural Radioelements

Although very large amounts of radioactivity can now be created artificially, interest in the radioactive elements which occur in nature has not declined. On the contrary, developments of nuclear technology have created a greater demand for radium and related elements, and have provided methods of converting one to another. Nevertheless, these elements remain exceptionally difficult to handle on account of their radiological characteristics, and the new Alpha laboratory has been necessary to provide facilities for chemical refining of radium and related elements, under the highest standards of protection.

This department also manufactures many radium appliances for therapeutic use at home and abroad, and maintains the nation's stock of medical radium which comprises more than 25,000 needles and tubes which are in almost daily use at radiotherapy centres. The hospitals also use more than 30,000 radon seeds annually. From industry there is a steady demand for neutron sources which are based on radium or polonium, for use in well-logging or in connection with nuclear reactors.

This article is extracted from the UKAEA Bulletin *Atom*.



One of the benches in the Alpha laboratory. It is divided up into a series of inter-connecting reaction boxes, each of which is made of glass-reinforced polyester resin and is faced with lead glass windows

FUTURE FOR FOOD IRRADIATION

COSTS REDUCED BY NEW ACCELERATOR

by Wolfgang Huber and August S. Klein†*

COST of processing foods by radiation, especially the capital investment, will be significantly lowered by a new radiation generator —the L-band linac (travelling-wave linear accelerator)—designed by the American company, Applied Radiation Corporation.

Take shelf-life extension of fresh foods by low-dose irradiation as a promising example. Here, one L-band linac will handle 9,200 lb/hr at 250,000 rad. Two conventional S-band linacs previously would have been required to handle 7,500 lb/hr, at over twice the capital cost.

Electron beam sources operating at high power and high energy have become a reality with the L-band linac. And this breakthrough opens up a whole new era in the economics of applied radiation.

Food radiation cost estimates have varied widely, and have been confusing. Based on a 0.25 megarad radiopasteurization dose, estimated processing costs using conventional electron generators vary from 0.1-1.1 cent/lb‡, including both direct and indirect linear accelerators. Estimated per-pound processing costs at the same dose level for fission products are 0.3 to 0.77 c.; for cobalt-60, 0.14 to 1.35c.; and for reactors, 0.12 to 0.73c.

From Actual Operation

Against this background, may we emphasize that our estimates for the L-band linac are taken from actual operating characteristics of the machine. In our comparisons with Co60 and Cs137, we have used projected figures.

Operating costs of the new L-band accelerator and a conventional S-band model are compared in Table I. Comparative cost per pound of a radiopasteurizing dose of 0.25 megarad-lb is given in Table II. The L-band accelerator shows up at less than one-fourth the operating cost of the currently available S-band linac and the future, estimated, costs for isotope sources.

For comparative purposes, the established costs of conventional food processing may be summarized as follows:

Frozen foods—2 to 3.5c./lb plus 0.2 to 0.4c./lb for freezing. Canned goods—0.15 to 0.5c./lb for heat processing of vegetables and 0.8 to 5c./lb for meats. The cost of heat processing of fruits is considerably less than 0.15c./lb, due to the fact that these acid products need very little heat for sterilization.

L-band processing costs of 3-6 mils‡/lb for shelf-life extension of fresh and processed foods are well within the economics of even a marginal food processing operation.

Second Look Wanted

Thus the economics of radiation processing are markedly improved. And indicated is a second look at radiation processes that had seemed too expensive.

The most likely candidates for radiation processing—because of quality improvement, convenience, novelty, and reduction of loss—are presented in Table III.

Radiation-sterilization requires doses up to several Mrad. At such levels the organoleptic changes often are objectionable. This, coupled with the need of prior enzyme inactivation, pretty much limits applications of immediate interest to

Table I.—Cost Calculations for Commercial, Low-dose Radiation-processing of Foods with (1) High-energy Electron Beam from Conventional (S-band) and (2) L-band Linear Accelerator (6,000hr/year operation, three shifts)

	S-Band Linac 8 MeV, 2 kW[1] installed[3]	L-Band Linac 8 MeV, 5 kW[2] installed[3]
	$	$
Return on capital investment[4]	4.25	4.25
Depreciation—10 yr	2.64	2.64
Utilities	0.50	0.50
Direct labour—operator, helper	5.00	5.00
Maintenance	24.60	8.80
Overhead, taxes, insurance	2.50	2.50
R. & D. costs[5]	2.30	2.30
Operations cost/hr	41.79	25.99
Cost/kWh	$20.90	$ 5.20

[1]Mark I-F4 linear accelerator, Applied Radiation Corp., Cost, $170,000

[2]Mark I-F5 linear accelerator, Applied Radiation Corp., Walnut Creek, Calif., Cost, $170,000.

[3]Cost for building alterations excluded.

[4]Earnings at 15 per cent./annum after taxes on capital invested during 10-year depreciation period.

[5]One mil/megarad-lb at 50 per cent. beam efficiency.

Table II.—Costs of Radiation Sources in $/0.25 megarad-lb

	Beam Utilization 50 per cent.	25 per cent.
L-Band linac	0.0028	0.0056
S-Band linac	0.0130	0.0260
Cobalt-60*	0.0150	0.0300
Caesium-137*	0.0280	0.0560

*Stockman, C. H., and Bauman, R. G.

*Wolfgang Huber Associates, U.S.A.
†Applied Radiation Corporation, U.S.A.

‡*Rate of exchange at time of writing, $2.8 = £1 sterling. 0.1 cent will therefore be equal to about one-tenth of a penny. 0.1 cent is called in relation to radiation costs a mil.*

poultry, pork, and a few lamb, veal, beef, and fish products.

A combination of ionizing radiation and heat may well give radiation the biggest boost in food processing. Such a combination would reduce off-flavour production due to high radiation doses, but still would inactive radiation-resistant enzymes.

Combined with aseptic packaging subsequent to the combination treatment, the process would provide complete freedom in choice of container. This, in turn, would mitigate one of the shortcomings of electron-beam processing.

Promising Future

Shelf-life extension, often referred to as radiopasteurization, has undoubtedly the most promising commercial potential. It achieves its effect by retention of top quality five to ten times longer than possible with existing methods.

Research indicates that radiopasteurization can be equally useful with meats, fish, produce, and a variety of other products, either fresh or prepared, that are prone to quick spoilage. With the low doses, objectionable changes in flavour, colour, or appearance are minimal or non-existent in most cases. This is particularly true when proper attention is paid to auxiliary processing conditions and the selection of suitable varieties.

A number of investigators have shown that refrigerated shelf-life of retail cuts of fresh beef, pork, veal, lamb and chicken can be extended by factors of 5 to 10 with doses of 200,000 to 300,000 rad. Particularly good effects are obtained when this treatment is carried out in the presence of an antibiotic.

Prepared meat products, such as sausages, luncheon meats, and frankfurters, have shown equally promising results. Shelf-life extension of seafood by low dose irradiation presents an opportunity to reverse the declining trend of the fresh fish market.

Spoilage of 25 to 30 per cent. of fresh fruits and vegetables is not uncommon between producer and final consumer. Shelf-life extension by low-dosage radiation is particularly attractive in this field, and the experimental results have been quite successful with many varieties.

Numerous investigations have firmly established that a dose of about 30,000 rad will kill eggs, terminate larvae development, and sterilize the adults of representative species of cereal-infesting insects. Among these are the bean weevil, granary weevil, rice weevil, confused flour beetle, sawtoothed grain beetle, cigarette beetle, lesser grain borer, and yellow meal worm.

Lack of Suitable Plant

The pronounced sensitivity of insect eggs to ionizing radiation makes this method particularly attractive in view of the shortcomings of fumigation and mechanical methods in this respect.

But efforts to commercialize such deinfestation of grains and cereal products have so far been largely stymied. One reason is lack of equipment of suitable design and at suitable costs and that is adaptable to the high-speed processes used in transport and loading and unloading of grain and bulk cereal products.

Volumes transported during the loading and unloading of grain elevators—or during the packaging of grains in bags and transport thereafter—approach 60-100 ton/hr. Thus, to cope successfully, two cross-fired electronic accelerators operating at 8 MeV and 4 kW each would be required. Such an installation could handle at 30,000 rad about 60 tons of grain (density 0.65)/hr, passing through the radiation field as a layer 3.8 in. thick.

The commercial value of ridding meat and fish of flukes and of marketing pork product guaranteed to be trichina-free should intrigue management and be a hit with the consumer.

In fact, interest may well be rekindled in radiating a host of different foods. This should be a result of the reduction of radiation processing costs to less than one-fourth, and of capital investment to one-half of previous estimates.

Table III.—Foods Most Likely to be Radiated

STERILIZATION[1] (2.0-3.5 Mrad) Destruction of Pathogenic and Spoilage Organisms	SHELF-LIFE EXTENSION[3] (0.1-0.5 Mrad) Retardation of Spoilage Bacteria, Moulds, Fungi	DEINFESTATION of Insects and Helminths (0.005-0.05 Mrad) Break of Reproductive Cycle
Meat: Beef hamburger; ham; pork-tenderloin roast, chops; pork-sausage; bacon; lamb chops; veal roast; chicken, turkey, cuts or whole. Prepared meat dishes.[2]	*Meat*[4]*:* Many varieties, either raw cuts or processed such as sausages, luncheon meats, spreads. Prepared dishes such as TV dinners, convenience items, gourmet foods.	*Elimination* of weevils, borers, beetles, worms, and similar pests from grains, cereals, cereal products, rice, dried foods, spices, tropical fruits, etc.
Fish: Cod, flounder, haddock, oysters. Prepared fish dishes[2].	*Fish*[4]*:* Many species, raw cuts such as fillets and steaks; cooked shellfish meat. Prepared dishes.	*Elimination* of helminths, nematodes (trichinella), cestodes (tapeworm), trematodes (flukes) from meat, fish and other foods.
Vegetables: Green beans; beets, broccoli, brussel sprouts.	*Produce*[4]*:* Many varieties of fresh fruits and vegetables.	
Fruit: None.	*Dairy Products*[4]*:* Dried eggs (Salmonella, 0.8 Mrad); fresh cheese; prepared dishes.	
Dairy Products: None.	*Baked Goods:* Brown 'n serve items, prebaked pies, batter, cakes.	

[1]Prior enzyme inactivation by heat where necessary.
[2]Combination of radiation and heat attractive because of synergistic action and thus quality improvement and cost reduction.
[3]Refrigerated or room temperature; extension, 3 to 10 times normal, depending on product and process.
[4]Prepackaged; anti-oxidant treated where rancidity a problem.

Westminster talks about...

by Peter Lewis—Our Parliamentary Correspondent

BIG BEN tolled the bewitching hour of midnight and the Finance Bill dragged its tired fiscal feet into the dawn of another month. Two and a half hours later the light on the Clock Tower was extinguished and the cry of " Who Goes Home?" echoed through the corridors.

Dangers of Sr-90

At two in the morning June was ushered in by **Mr. John Morris** (L., Aberavon) who introduced a debate on the Second Report of the Agricultural Research Council's findings on the dangers of strontium-90 in milk. Mr. Morris said that the increased rate of contamination had been higher than anyone had anticipated, todays figure being 9.6 against 0.5 in 1954. Mr. Morris called upon the Government to explain some of the vagaries of the Report such as the question of whether accumulative or recent deposition was responsible for contamination increase. There was also some conflict over the question of what defined the threshold of safety. Replying for the Government, **Miss Edith Pitt,** Parliamentary Secretary to the Ministry of Health, welcomed the opportunity of the debate to dispel the idea that there was any danger from milk produced in Britain. Miss Pitt told the House that the experts were emphatic that the present levels of Sr90 in milk were no cause for alarm or concern. She had been advised that the contamination was predominantly the result of recent falls, but contamination figures were decreasing and were expected to continue so.

Revised N-Programme

The issue of a White Paper on the Government's revised civil nuclear programme, caused considerable comment. **Mr. Frederick Lee** (L., Newton) having only just received a copy of the Paper, told the Minister that he had not had time to read it, but didn't the Minister think it a great pity that such a young, modern and public industry as nuclear power generation should be cut back. Mr. Lee also pondered upon the effect this retardation would have on the NCB's programme.

Ministerial Logic

Considerable amusement was caused by the Minister's esoteric statement that, rather than a cut-back it was a deferment of acceleration. The Minister of Power, **Mr. Richard Wood** added that the whole reason for the change in the civil nuclear programme was that the break-even point between nuclear and conventional generation would be later than anticipated. The spate of questions that followed was interrupted by Mr. Speaker and the Minister indicated that he would make a statement at a more appropriate time.

UK-EURATOM Link

Mr. Roy Mason (L., Barnsley) asked if the Secretary of State for Foreign Affairs was satisfied with the technical collaboration agreement existing between the United Kingdom and Euratom, what progress had been made and would the Secretary now consider a closer relationship with Euratom. The Minister, **Mr. J. D. Profumo** said in answer, that he was satisfied that the agreement provided a basis for fruitful technical collaboration. He went on to say that the Continuing Committee for Co-operation, on which the Minister for Science and the chairman of the AEA, represented the United Kingdom, had had a valuable first meeting and there had been useful exchanges of information in the Joint Working Group of Officials of the UKAEA, and the Euratom Commission and at meetings of experts on specific subjects.

Experimental Reactors

The number of experimental nuclear reactor projects under observation and construction was the subject of a further question by **Mr. Roy Mason,** who also requested details of the types of reactors and their purpose. Taking on his now familiar role of Minister of Science, **Sir David Eccles** the Minister of Education, told Mr. Mason that the AEA endeavoured to keep under observation experimental reactor projects in all parts of the world. At present they had two reactors under construction, two others had recently been completed. The former were in support of the next stage in the commercial development of the gas-cooled reactor system, the latter were experimental reactors to explore the physics and engineering of yet more advanced systems. Sir David then gave details of the Authority's research and experimental reactors.

Safety Committee

Mr. David Price (C., Eastleigh) asked the Minister of Power what arrangements he had made to obtain independent advice on the safety of nuclear power installations licensed under the Nuclear Installations (Licensing and Insurance) Act, 1959. Mr. Wood said that he and his Rt. Hon. Friend, the Minister of State for Scotland, had appointed a Nuclear Safety Advisory Committee and gave the following information regarding the Committee's terms of reference and its composition.

Terms of Reference

To advise the Minister of Power and the Secretary of State for Scotland on any matters affecting the functions of those Ministers in relation to safety under the Nuclear Installations (Licensing and Insurance) Act, 1959, which may be referred to them by either of those Ministers or which in the Committee's opinion ought to be brought to the notice of either Minister, apart from any such reference.

Chairman of the committee will be Sir Alexander Fleck, KBE. Other members:—Dr. T. E. Allibone, CBE, Mr. G. F. Bullock, Sir John Cockcroft, OM, KCB, CBE, Mr. P. Connor, Dr. S. C. Curran, Professor P. I. Dee, CBE, Professor J. Diamond, Mr. P. T. Fletcher, CBE, Professor J. E. Harris, Mr. F. Hayday, Sir Willis Jackson, Major-General S. W. Joslin, CB, CBE, Professor J. M. Kay, Dr. John Loutit, CBE, Mr. T. W. McCullough, OBE, Dr. A. S. McLean, Sir George McNaughton, CB, Mr. R. E. Newall, Mr. H. N. Pemberton, Colonel G. W. Raby, CBE, Mr. L. Rotherham, Sir William Slater, KBE, and Dr. F. A. Vick, OBE.

'NUCLEARIST' writes . . .

REMEMBER I mentioned recently the "Isotopes Shop" opened in Moscow. It seems the idea was a sound one, for the UKAEA now has a similar facility at its London HQ, where industrialists and research workers can gather to talk and discuss with experts the applications of isotopes to their own particular problems.

* * *

Although recent figures indicated a decrease in the fall-out radiation over Britain during the last year, the general population's absorbed radiation, from industrial usage and nuclear power plants, has actually increased by about 1 per cent. Stricter controls have become necessary, but even so, the radiation hazard may present a real problem before long, with the marked increase in industrial utilization of isotopes and other radiation-producers. And how long will it be before the uncontrolled testing of nuclear weapons is resumed? This will put the hazard even more before the public eye.

By an overwhelming majority, the Programme and Budget Committee of the World Health Organization resolved recently that this body should extend its guidance and assistance in the problems associated with radiation and radioactivity. The U.S.S.R. submitted a resolution by which WHO should undertake to protect mankind from harmful environmental factors, and try to put an end to nuclear weapons testing. Actually, this resolution was withdrawn, since it presented many thorny political aspects, and perhaps was too idealistic, anyway.

* * *

As radiation levels rise, so do salaries everywhere. Throughout the Government scientific profession there have been increases in pay, and this naturally applies to the employees of the UKAEA. Increases for scientific officers are from £55 to £290, and for experimental officers £50 to £250. Coming as they do at a time when the nuclear power programme is being slowed down, there are many who feel that this is another case of more pay for less work. But this is a jaundiced attitude to adopt.

* * *

The AEA's revised edition of "Glossary of Atomic Terms" is a commendable achievement. Within its modest compass it embraces about 500 definitions. Such a pocket-sized publication could hardly expect to be exhaustive, and yet in comparing entries and omissions one seeks in vain for the rationale of them. For example, Jülich is included, but not Risö, Petten, and Kjeller. Alpha appears, but not Apsara; meson and deuteron are there, but not hyperon, lambda particle, and triton. No mention is made of the charge on mesons, Müller and Nucléaire are misspelled, röntgen and roentgen vie for priority, actinides and actinium are omitted, and the definition of a quantum is far from satisfactory. Nevertheless, I think the book is worth the price charged, namely 3*s*. 6*d*.

* * *

"1960 will be for ever memorable in the annals of atomic science . . . one scientific laboratory . . . opened its doors to release irradiated food and flower seeds for lay experimentation." In these words there bursts upon a surprised world another great idea, and "the shock was staggering." We are accustomed to the fanfares of American filmshows now, and the generosity with which superlatives are lavished, so we need not be unduly unnerved. I have quoted from the preface to Muriel Howorth's latest book, "Atomic Gardening." By the time we have read also the foreword by a well-known gardening enthusiast and the introduction by a scientist, the effervescence has died down a little, and we realize that the new Atomic Gardening Society which the author has inaugurated certainly incorporates some ardent pioneers willing to get down to studying mutations in plants grown from irradiated seeds.

I recently talked to a member of the Board of Consultants of this Society, and found that they aim to try to improve man's lot by developing new and improved food crops. It is somewhat remarkable, then, that the seeds passed around among the members are those of maize, ground-nut, petunia, tomato, and marigold, none of which, however improved they may become, is likely to ensure the survival of the British race. Surely, unless this Atomic Gardening Society is not simply a stunt, their efforts should be devoted to improving crops more likely to be valuable in our own economy. I suppose the answer is that the members are entirely dependent upon supplies of seeds from the U.S.A., where maize and peanuts are more staple diet than they are in our own isles. However, I feel that there may be something in Mrs. Howorth's idea, if only it could be guided along the right channels. Her enthusiasm is too good to be wasted.

* * *

Dr. D. R. Davies, of the Wantage Research Laboratory, in his recent talk to the Royal Society of Arts, gave some very interesting and sobering opinions of this plant mutation business. He pointed out that mutations are extremely rare, and in any case only one in 800 of them is likely to be of use, so that immense plant populations are involved if anything useful is to come out of the study. The study furthermore must be done scientifically. Chemical mutagenic agents have proved more effective than X-rays, and need not damage the chromosomes as the radiations do. Dr. Davies, in his concluding words, gave some indication of the various factors which must be taken into account into mutation work, and these should be read by the members of the Atomic Gardening Society, I think.

* * *

From amateur atomic gardening to scientific research is perhaps a big step, but I am prompted to mention a lecture given by M. Baranger, given at the Ecole Polytechnique, Paris. The speaker tried to answer the question: "Do plants obtain all their constituent elements from the environment, or are they capable of synthesizing elements not present in that environment?" He described experiments which, he said, suggest that plants "under certain conditions" can form elements which did not exist in their environment. Unfortunately, his results are capable of interpretation in much simpler terms, as careful consideration would quickly show. Could someone establish that Baranger's suggestion were indeed true, it would raise some fascinating implications.

NUCLEAR NEWS

- **I.A.E.A. 1961 Budget Proposals** *(Page 376)*
- **60 MW Space N-Plant Predicted** *(Page 377)*
- **Report on Radioactivity at Sea** *(Page 378)*

New Reactor for U.K.A.E.A.

A ZERO energy fast reactor is to be built by the Atomic Energy Authority at Winfrith Heath. To be known as ZEBRA (Zero Energy Breeder Reactor Assembly) it will permit the study of the neutron physics of a wide variety of fuel assemblies containing uranium and plutonium. The purpose of the reactor will be to provide information required for the construction of a prototype fast reactor. Work carried out on it will be complementary to that undertaken at Dounreay. The reactor is planned to be commissioned during 1962.

Stimulant Isotope

IT was announced recently that a new radiochemical compound, Caffeine-C-14, has been made commercially available by Tracerlab. Caffeine, usually classified as a stimulant, is a normal constituent of coffee, tea and other organic materials, and is used in its pure form for various medical purposes. It is expected that the new compound will help medical and biochemical researchers in gaining a deeper understanding of the effects of caffeine on cardiac, respiratory and psychic functions.

Gas and N-Energy

THE relationship between coal, electricity and nuclear power from the point of view of the gas industry was reviewed by Mr. Duncan D. Melvin in his presidential address to the annual meeting in Edinburgh of the Institution of Gas Engineers. Mr. Melvin, who is a member of the Scottish Gas Board, said that the position that nuclear energy might occupy in the supply of total energy requirements in the next decade or two was uncertain. An increased contribution by nuclear power was inevitable, but production costs, limited capital, and the solution of difficult technical problems all indicated that this was a road along which the electricity industry must hasten slowly. "The immediate need," he said, "is for a balanced commercial policy for coal that will ensure the well-being of both secondary refined fuel industries, and this requires reversal of the price trends of the past two decades." The future dimensions of the coal industry, he said, depended upon its ability to provide a source of energy that could be processed to acceptable refined forms at competitive costs. Neglect of the gas industry by the coal industry could only be to the detriment of the coal industry and the nation.

C.E.R.N. Matters

CERN is to start seriously thinking about the construction of a "new tool of research" for use in the 1970s. This was agreed upon at a recent meeting of the Council when Professor E. Amaldi, chairman of the CERN scientific policy committee, said that the state of research in high energy physics in 10 years' time would compel the organization to use such a machine. The importance of this instrument would be, in 1970, comparable to that of the 25 GeV synchrotron now in operation at Geneva. The appointment of Mr. J. B. Adams as acting director-general of CERN, was confirmed by the Council. As also was the agreement between CERN and the Federal Institute of Technology, Zurich, for collaboration on the construction and use of a 150 m cloud chamber. Mr. Adams announced that negotiations for the exchange of scientists between CERN and the research centre at Dubna, near Moscow, had been successfully concluded.

H.T.G.C.R. Fuel Loop

A SPECIAL nuclear fuel test loop will be designed, built and operated by the U.S. General Electric for the General Dynamics Corporation at General Electric's Vallecitos Atomic Laboratory near Pleasanton, California. The loop will be used for extensive irradiation tests of prototype fuel for the 40 MW(e) high-temperature, gas-cooled reactor now being designed by General Dynamics for the Philadelphia Electric Co. and the High Temperature Reactor Development Associates, Inc. The loop will be helium-cooled, with coolant temperatures up to 1,400°F., pressures up to 350 lb/sq.in., and coolant flow at the rate of 0.15/sec or higher. Design work on the loop has already begun and it is proposed that construction will soon be started.

C.E.G.B. Awards

TWENTY-ONE boys and three girls have been awarded university scholarships by the Central Electricity Generating Board. The awards are made under the electricity supply industry's scholarship scheme for school leavers. The value of each award is £400 per annum at a university in Great Britain; for Cambridge and Oxford it is £450 per annum. The object of the scheme is to enable suitable recruits to the industry to attend university to study engineering or a science subject. During certain of the university vacations practical training is given in the industry and upon completion of the course the graduates will join the Generating Board's staff, mainly for research work. The 24 awards were made after interviews with some 300 applicants at nine centres throughout the country.

Accelerator Contract

A CONTRACT has been awarded to Radiation Dynamics, Inc., by Grumman Aircraft Engineering Corp. to develop and build a positive ion Dynamitron accelerator for use by its research department in space environment studies. The accelerator employs RDI's new high-current Dynamag ion source, which is a modification of the duo-plasmatron source developed by Oak Ridge National Laboratory. The accelerator utilizes a cascaded rectifier system in which all the rectifiers are driven in parallel from a high frequency oscillator.

EURATOM Visitors at Argonne

Recent visitors to the Argonne National Laboratory, Illinois, were two senior members of EURATOM. They were Dr. Heinz Krekeler (*left*) of Germany, and Mr. Emmanuel Sassen (*right*) of the Netherlands, seen here with Dr. Norman Hilberry, director of Argonne. The visitors were touring the United States to discuss technical and economic aspects of large-scale nuclear power plants and to talk about the problems associated with nuclear safety, the application of radioisotopes, etc.

N-Briefs

Dawe Instruments, Ltd., have been taken over by Simms Motor and Electronics Corporation, Ltd., who recently acquired Cawkell Research and Electronics, Ltd.

* * *

Atomic Power Constructions, Ltd., and the GEC-Simon-Carves Atomic Energy Group have now agreed to join forces to design and build nuclear power stations in this country.

* * *

What is believed to be the world's largest piece of highly heat-resistant pyrolitic graphite has been produced in the Research Laboratory of U.S. General Electric. The rectangular piece, $\frac{1}{8}$ in. thick, measures 17 in. × 31 in.

* * *

British Insulated Callender's Cables, Ltd., have opened a new depot at Silverdale Road, Hayes, Middlesex (telephone Hayes 8241). It will carry a comprehensive stock of rubber, thermoplastic and mineral insulated cables and accessories.

* * *

Ghana is not yet a member of the IAEA as reported in NUCLEAR ENERGY in May. Her application has been approved by the governors, admission rests however with the general conference to be held in September.

* * *

The first United States patent issued to a private company for an entire atomic reactor system has been granted to North American Aviation, Inc., for a reactor developed by its Atomics International division. The patent was issued in the name of John W. Flora, group leader of reactor kinetics for Atomics International, and is for the laboratory reactor, designed by Flora and built by the company.

* * *

Electronic Instruments, Ltd., of Richmond, Surrey, have been bought up by the Cambridge Instruments Co., Ltd. They will continue to operate under their own name. Electronic, established 15 years ago, manufacture a range of measuring units used in scientific, industrial and nuclear fields. They operate two factories at Richmond and have associated companies in France, Canada and Australia.

* * *

New high-strength, low-cost steels for high temperature use in nuclear power reactors are being developed by Atomics International, a division of North American Aviation, Inc., and United States Steel Corp. The development programme conducted for the U.S. Atomic Energy Commission, may lead to lower capital and operating costs and increased efficiency of nuclear power plants. It involves alloy modifications to low-cost chromium-molybdenum steels to increase their high temperature strength and corrosion resistance.

* * *

High Voltage Engineering Corporation, manufacturer of radiation-producing particle accelerators, have acquired all the stock of Applied Radiation Corporation (ARCO) of Walnut Creek, California, a leading producer of microwave linear accelerators. ARCO continues to operate as a separate corporation under its present management, but will have close management and technical affiliation with High Voltage. Sales will be integrated by High Voltage Engineering, making use of its expanding organization and representation in key market areas both in the U.S. and abroad.

* * *

The activities of Head Wrightson Processes Ltd., a subsidiary of Head Wrightson & Co., Ltd., have been extended to cover all Head Wrightson's nuclear research and nuclear power interests. Aimed at streamlining operations in this field, this reorganization will greatly strengthen the company's services at present offered to the nuclear industry both in this country and abroad. With headquarters at Yarm-on-Tees, Yorkshire, Head Wrightson Processes will be responsible for carrying out the work at Bradwell and Latina nuclear power stations in addition to the research reactor projects in Denmark and Germany.

* * *

A consignment of electronics equipment donated by France to the International Atomic Energy Agency has arrived at the Agency's headquarters in Vienna. The equipment which will be used for radioactive measurements, includes a complete installation for Geiger-Mueller counting and a unit for low background counting. A second consignment, which is expected to arrive in March, will include a unit for gamma-gamma coincidence counting and a new type of cathode ray oscilloscope. The total value of the equipment is 150,000 new French francs (approximately U.S. $30,000).

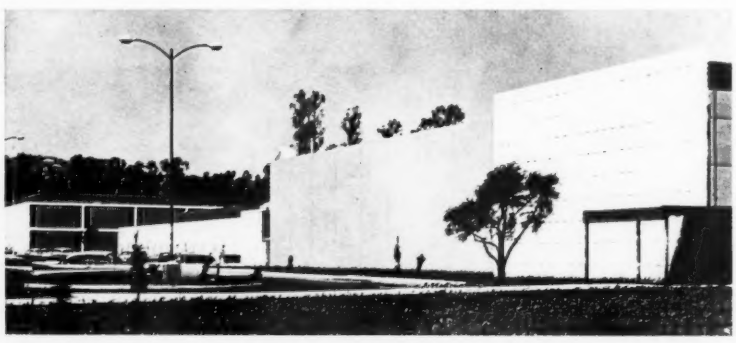
* * *

The U.S. Atomic Energy Commission has issued a construction permit to the Georgia division of Lockheed Aircraft for a low-power, pool-type nuclear reactor to be used for exhibition purposes in tours of four South American countries. Lockheed at Marietta, Ga., said the reactor has been fabricated and is now in process of erection at the Georgia Nuclear Laboratories near Dawsonville. After tests and approval, the reactor will be leased to the AEC and will be operated by Lockheed scientists under contract at the Argentina Sesquicentennial celebration in Buenos Aires in the autumn.

I.A.E.A Budget Plans

THE board of governors of the International Atomic Energy Agency has proposed an 8.5 per cent. increase in the Agency's budget for 1961 over that for the current year. The main feature of the budget is that while the administrative and organizational expenses are stabilized at the present level, it provides for some expansion of the Agency's functional and operational activities, such as technical assistance, training, assistance in the field of research, and scientific and technical services to member states of the Agency. The budget proposals, finalized by the board during its recent series of meetings in Vienna, will be submitted to the Agency's general conference which meets in September for its fourth regular session. The total budget, which provides for an expenditure of $7,968,000, is divided into two parts: regular and operational. Expenditure under the regular budget is met from the assessed contributions of member states, while the operational expenditure has to be met out of the Agency's General Fund which is made up of voluntary contributions. The proposed operational budget for next year is $1,800,000, as against an approved budget of $1,500,000 for 1960. The proposed budget for next year provides $800,000 for the programme of fellowships and training and $600,000 for technical and research assistance. A sum of $349,000 is proposed to be allocated for equipment and operating costs of the Agency's laboratory at Seibersdorf near Vienna and $51,000 for the operation of mobile radioisotope laboratories. In addition, the Agency also expects to have at its disposal approximately $785,000 as its estimated share of the funds of the United Nations Expanded Programme of Technical Assistance. The regular budget provides for an expenditure of $6,168,000. Apart from organizational and administrative expenses, some of the important allocations proposed under the regular budget are: $703,000 for scientific and technical services and laboratory charges, $255,000 for the dissemination of information, $170,000 for scientific meetings, $154,000 for the organization of panels and committees of experts, and $130,000 for the despatch of special missions.

New Office Block



New headquarters of Atomics International, a division of the North American Aviation, Inc., California

Alloys Renamed

HENRY WIGGIN & Co. announce new names for certain of their high-nickel alloys. This renaming has become necessary because of the wide diversity of compositions which have been developed over the last few years to meet specific material requirements. INCOLOY DS is the new name for the alloy previously known as NIMONIC DS. This is essentially a nickel-chromium-iron alloy, useful in oxidizing conditions at temperatures up to 950°C. In reducing atmospheres, INCOLOY DS may sometimes be used at even higher temperatures. VALRAY 1 is the new name for BAC BRIGHTRAY, an 80/20 nickel-chromium alloy used extensively for the coating of automobile exhaust valves.

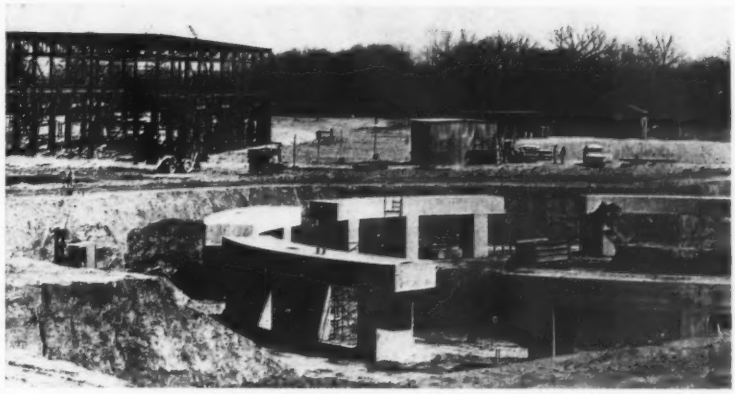
Contract for Shaft

A $765,000 contract for the construction of a 1,200 ft deep shaft has been awarded by the United States Atomic Energy Commission to the American subsidiary company of the Cementation group. The shaft will provide access to a drivage designed for the detonation of a nuclear device for the development of atomic energy for peaceful purposes. Known as "Project Gnome," the site is at a point 25 miles south-east of Carlsbad in the salt beds of New Mexico. Announcing the award of the contract today, a spokesman for the Cementation group's head office in London said the project was scheduled for completion by June, 1961.

Safety in Japan

THE Director of the International Atomic Energy Agency's Division of Safeguards, Mr. Roger M. Smith, has been in Japan to advise the Government on the introduction of a system of management control of nuclear materials. Such a system would have to include methods of accounting, stock-taking, measurements and storehousing of nuclear fuels, such as natural and enriched uranium, thorium and plutonium. A system of adequate stewardship of nuclear materials has been elaborated by the International Agency during the last 18 months and has been tested in practice at nuclear installations in Canada, the United Kingdom and the United States of America. Similar systems of "internal safeguards" are already in operation in several countries having large-scale nuclear energy programmes and IAEA is prepared to render assistance, on request, to those member countries now embarking upon atomic energy projects.

Cyclotron Site in U.S.A.



Construction of the Zero Gradient Proton Synchrotron at the site of the Argonne National Laboratory, Illinois, progresses. These concrete structures will support the 5,000-ton magnet ring in which particles will be accelerated to energies of up to 12.5 GeV

"N-Station in Space by 1970"

A WESTINGHOUSE Electric Corporation executive has predicted that by 1970 the United States will be able to orbit a nuclear-powered electric generating system with a capacity of 60,000 kW—enough power to supply the residential needs of a city of about 120,000 persons on earth. John W. Simpson, vice-president in charge of the company's atomic power division, told scientists and engineers attending the 1960 American Nuclear Congress that the technology of the next decade will permit the U.S. to maintain astronauts in space exploration with a large-scale satellite auxiliary power system that uses a reactor as its source of energy. He also discussed a second major application of atomic power in astronautics, another type of nuclear engine that will offer a means of rocket propulsion of "more than twice the efficiency of its chemical counterpart for a given rocket frame." Predictions on the operation of a large-scale generating station in space are based on the belief that by applying today's technology, the U.S. could generate 1 kW of electric energy with 8 lb of payload, Mr. Simpson explained. "I believe that by 1970, it is reasonable to expect to get 1 kW of power for every 4 lb of payload," he added. "Thus, 120 tons of payload would give you a 60,000 kW output. Of course, we would need boosters powerful enough to put such weights into orbit, but such boosters are planned and, with the development of nuclear rockets, far heavier payloads will be possible." For interplanetary space travel, probably nothing close to this amount of power will be needed, but the availability of such energy could have a profound effect on such plans, Mr. Simpson noted. "Consider that in the more hostile environments of earth, such as our deserts and seas, the limiting factor of human survival is power. If you supply enough power and conversion equipment, you can support human life in any type of environment. This will be true in outer space, the most hostile environment for man which we can anticipate. As more and more power can be supplied manned flights, lunar landings and interplanetary explorations could become quite supportable. I think demands (such as these) are forthcoming," he continued, "and we will be lucky to stay close to them, let alone ahead of them."

I.A.E.A. Assignments

THE International Atomic Energy Agency is sending 20 experts to various countries this year. Some of the countries will also receive equipment needed by the experts in their work. Afghanistan is to be sent a nuclear physicist who will assist the government in formulating a nuclear programme for the country, train staff and lecture at the University of Kabul, and assist in the establishment of a nuclear physics laboratory at the university. An IAEA biochemist will work at the Austrian Cancer Research Institute, Vienna, to advise on the use of radioisotopes in cancer research and to advise on the setting up of a radioisotopes laboratory. The Agency will provide equipment for this work. Several experts are being sent to Brazil. One will be an expert in prospecting for nuclear raw materials and another a nuclear geologist. In connection with the creation of a division of nuclear metallurgy at the Institute of Atomic Energy the IAEA are sending a nuclear metallurgist. Another expert sent to Brazil will assist in the training of chemists in radiochemistry and isotope separation as applied to isotope production. He will also be concerned with the organization and preparation of the research programme of radiochemical laboratories. A fifth expert will advise the Brazilian government on the legal rules on third party liability and insurance for nuclear hazards relating to the Mamcuba nuclear power project. Two experts will be sent to Iran to assist in an exploration of Iran's radioactive mineral resources and a survey of the possibilties of mining and producing uranium in the future. Two experts are also going to Iraq. One will be an agriculturist who will work on investigations into soil reclamation, fertility surveys and crop improvements, and the other, a medical expert who will work at the radioisotopes department of the Republic Hospital, Baghdad. Equipment will be supplied by the Agency for some of this work. Korea has a TRIGA Mark II reactor at Seoul and to advise the Atomic Energy

Research Institute on health matters relating to this project, the Agency is sending them a health physicist. The Philippines are receiving the services of a radiochemist and also a range of equipment, including counters, ionization chambers, and ratemeters. The expert sent to Turkey will advise the government on the planning of a detailed long term nuclear energy programme, and the establishment and operation of the facilities and laboratories necessary to implement such a programme. The expert will also advise on the setting up and utilization of a sub-critical assembly planned for the Ankara University. A legal expert will be sent to Venezuela to advise the government on legislative and administrative problems relating to its nuclear energy programme. Three Agency experts will be sent to Yugoslavia, together with some equipment. An agriculturist will work at the Yugoslav Institute for the Application of Nuclear Energy in Agriculture, Veterinary Sciences and Forestry, Belgrade, and will assist in the organization, development and equipping of a laboratory for the Institute. A second expert will initiate clinical research work at the medical radioisotope laboratories at Belgrade, Ljubljana and Zagreb. He will also lecture on the application of radioisotopes. A biochemist will be attached to the Institute for Biology, Zagreb, to assist in the fight against fasciolosis, a cattle disease estimated to cost 8,000m. dinars a year.

U.K.A.E.A.'s 6th Annual Report

Brief details and comment on the Atomic Energy Authority's report for 1959-60 appear on page 349 of this issue.

O.M.R.E. Servicing

THE U.S. Atomic Energy Commission has authorized the Fluor Corporation, Ltd., to perform architect-engineering services in conjunction with the modification of the Organic Moderated Reactor Experiment (OMRE) at the National Reactor Testing Station near Idaho Falls, Idaho. The OMRE was originally designed to test the feasibility of a nuclear power reactor cooled and moderated by an organic fluid. Successful operation of the reactor has indicated a need to continue engineering development of the concept. The modification will extend the operating usefulness of the facility over the next few years. Included in Fluor's design work will be a new building to house the reactor, modifications of utilities systems, a laboratory and repair facilities. The total cost of the project will exceed $1m.

I.A.E.A. Board Changes

AUSTRALIA, Belgium, Brazil, Canada, Finland, France, India, Japan, Poland, the Union of South Africa, the U.S.S.R., the United Kingdom and the U.S.A. have been designated members of the board of governors of the International Atomic Energy Agency for 1960-61. The board is composed of 23 members—13 designated by the board itself and 10 elected by the Agency's General Conference. Designation of members is based on a set of statutory criteria, including state of advance in the technology of atomic energy and geographic distribution. Of the 13 members designated for 1960-61, 10 are members of the present board, and three new members being Belgium, Finland and Poland. The three members of the present board not designated for 1960-61 are Czechoslovakia, Norway and Portugal.

Waste Disposal at Sea Report

THE release of highly radioactive wastes into the sea cannot at present be recommended as an operational practice, but the sea disposal of wastes of low and intermediate activity may be safe under controlled and specified conditions. This is one of the conclusions reached by an international panel of experts set up by the International Atomic Energy Agency. The panel, whose report was recently released in Vienna, was composed of experts from nine countries, with Mr. Harry Brynielsson, head of the Swedish Atomic Energy Co., as chairman. In convening the panel in October, 1958, the director general had taken into account a recommendation of the International Law Commission which, in one of the Articles Concerning the Law of the Sea, had stated that IAEA " should pursue whatever studies and take whatever action necessary to assist states in controlling the discharge or release of radioactive materials to the sea, promulgating standards, and in drawing up internationally acceptable regulations to prevent pollution of the sea by radioactive materials in amounts which would adversely affect man and his marine resources." The panel conducted its studies at a series of meetings at the Agency's headquarters in Vienna and its conclusions are contained in a report recently submitted to the director-general, who has transmitted it to the Agency's member states. The experts have pointed out that the first principle must be the safeguarding of man against damaging effects of radiation and only those waste disposal methods should be considered as do not involve any risk that is unacceptable either to the individual or to the population at large. In assessing the safety of proposed disposal operations, the most recent recommendation of the International Commission of Radiological Protection should be used as a guide. The panel has recommended that all radioactive wastes disposed of into the sea, with the exception of those incidental to the operation of nuclear-powered ships, should be released into designated disposal sites in conformity with conditions specified for the particular site. Wastes from nuclear ships should be released in such a way as not to limit the harvest of marine products. Further, each disposal site should be designated by responsible national or international authority which should also set out the conditions of disposal for the site. It should also provide for any necessary monitoring of the area to verify that safe conditions are maintained and collect disposal records that would adequately indicate the state of the site. Another important recommendation of the panel is that all authorities setting up disposal sites should supply a suitable international authority with information necessary to maintain an adequate register of waste disposals into the sea. As regards the disposal of wastes from nuclear ships, the panel has stated that a record should be maintained on every ship for inspection by port authorities, and all disposals in harbours and national waters should be in conformity with conditions laid down by the local authority. Disposal in international waters should be in conformity with conditions specified in the vessel licensing or by an international authority.

NEW RELEASES

" Hinkley Point—Part 1 " covers dramatically the first two years of construction of the 500 MW nuclear power station being built at Hinkley Point, Somerset, by the English Electric-Babcock & Wilcox-Taylor Woodrow Atomic Power Group for the Central Electricity Generating Board. Design stages, site preparations, building of access roads, and a 3,500 ft sea wall, reconstruction of the old Roman port of Combwich, and the fabrication and erection of the 400-ton Goliath crane are shown, together with sequences showing the labour camp, various stages in the construction of the reactor buildings and turbine hall, and the Goliath crane's first and heaviest lift. There are also some animated sections illustrating the principles of a nuclear reactor. The film, produced for the group by Technical and Scientific Films, Ltd., in association with the Film Producers Guild, is in colour and runs for 29 minutes. It can be obtained in either 35 mm or 16 mm gauge and is available free of charge to engineering, industrial and other associations, government departments, universities, technical colleges, etc.

" Das Leben Mit Dem Atom " (" Life with the Atom "), made by Ifag-Films, of Wiesbaden, Germany, surveys the development of nuclear research for peaceful purposes, with emphasis on this work in the field of agriculture, medicine and industry. It is in black and white, runs for 13 minutes and is on 35 mm gauge. At present only a German version is available.

" Electric Surface Heaters," made by Isopad, Ltd., is about the production of the full range of the firm's heating equipment at their Borehamwood factory. It also illustrates the many applications to which this useful and versatile form of heating can be put (including installations at the F. W. Berk chemical plant, a Pye factory, Esso's new refinery at Fawley, the Bristol Aircraft Co., and at the Woomera rocket testing range. The film is in black and white, runs for 25 minutes and is available on 16 mm gauge. Commentary is spoken by television personality Richard Baker.

PEOPLE... in the NUCLEAR NEWS

Recently arrived in Japan to take up his appointment as chief resident engineer of the nuclear power station project at Tokai-Mura is **MR. K. A. LOWE,** BSc(Eng), ACGI, AMIMechE. Travelling with him from Britain was **MR. R. D. HARVEY,** AMechE, deputy chief engineer (electrical and mechanical) of the British General

Mr. K. A. Lowe

Mr. R. D. Harvey

Electric Co., of Japan Ltd., who are building the Tokai-Mura station for the Japan Atomic Power Co. With the arrival of Mr. Lowe and Mr. Harvey, British GEC staff in Japan now numbers 22. Mr. Lowe, who was educated at the Haberdashers' Aske's School, Hampstead, and Imperial College, London, was from 1946 until 1951 with the English Steel Corporation. He then joined the Esso Petroleum Co., to eventually become resident engineer at their Fawley refinery, Hampshire. Mr. Lowe joined GEC last year. Mr. Harvey, educated at the Royal Technical College, Glasgow, joined GEC in 1956, before which he was with John Brown and Co., Ltd., and with Constructors John Brown Ltd.

" For his distinguished service and leadership in the developments of nuclear energy." **DR. WALTER H. ZINN,** vice-president in charge of the nuclear activities of Combustion Engineering Inc., has been created a fellow of the American Nuclear Society. Dr. Zinn, who served as the Society's first president, was at one time director of the Argonne National Laboratory and was founder and president of the General Nuclear Engineering Corporation, which was acquired by Combustion Engineering in 1959. He worked on the design of the early Chicago piles and contributed to the design and development of the experimental boiling water reactor. Dr. Zinn was recently awarded the Ford-sponsored "Atoms for Peace Award" and his scientific achievements were further recognized about the same time by his appointment to the President's Science Advisory Committee.

Appointed project engineer for Advanced SNAP programmes in the nuclear division of the Martin Co., America, is 36-year-old **MR. JUSTIN L. BLOOM.** A chemical engineer with wide experience in the handling and use of radioisotopes, Mr. Bloom has been chief of the materials management branch of the San Francisco operations office of the USAEC for the last four years. Before that he had been with the Shell Chemical Corporation for four years, with the California Research and Development Co., and with the Lawrence Radiation Laboratory, California.

W. G. Pye & Co., Ltd., have appointed **MR. NEIL FENWICK** as sales promotion manager. For the last four years he has been in the company's homes sales department.

Recently elected to the board of Humphreys and Glasgow Ltd., are **MR. R. LANGFORD** and **MR. I. H. PHILLIPPS.** Mr. Langford, who is 40, has been with the company since 1946 and an associate director since 1957. He is chief contracts manager and was formerly head of the company's underground gasification department. Mr. Phillipps, also an associate director since 1957, joined the firm in 1945.

At Argonne National Laboratory, Illinois, new major appointments have been made. **MR. JOSEPH M. HARRER** of the reactor engineering division, has been transferred to the staff of the particle accelerator division to assist division director Dr. Albert V. Crewe with design co-ordination and operational problems relative to the Zero Gradient Synchrotron (ZGS). **DR. JOHN GILROY** has been appointed acting director of Argonne's electronics division, succeeding Thomas Brill, who recently resigned. The electronics division, with major service responsibilities to the entire laboratory, has been designated a technical services division under the general administration of **MR. JOHN T. BOBBITT,** technical services manager. **MR. EDWARD WIMUNC** continues as project manager for EBWR but takes on added responsibilities, while **DR. HAIG ISKENDERIAN** has been appointed project physicist for EBWR and **MR. JACK HAUGSNES** has taken over the duties of experimental physicist.

MR. RICHARD FAIREY, has retired from the board of The Fairey Co., Ltd., and relinquished his position as vice-chairman on account of ill health. The elder son of the late Sir Richard Fairey, MBE, founder of the Fairey Co., joined the company in 1936 in the jig and tool office. After the war he re-joined Fairey as works manager, later becoming general manager and a director. During the war Mr. Fairey lost both of his legs. Despite his disability he became an outstanding private pilot during the post-war years and was one of the first businessmen in this country to use a helicopter as a personal vehicle.

Guest speaker at a recent meeting of the Parliamentary and Scientific Committee held to discuss the possibility of instigating a British space programme was **DR. DENIS TAYLOR,** a director of Plessey Nucleonics Ltd., Dr. Taylor, who specializes in instrumentation, measurement and control, was for 12 years head of the electronics division at Harwell before joining Plessey in 1957.

LORD HALSBURY, of Joseph Lucas (Industries) Ltd., is the chairman of the recently formed electronic firm of LCE Ltd. Vice-chairman is **MR. JONATHAN H. LASLEY,** of Collins Radio Co., of England. LCE Ltd., is jointly owned by Lucas (through their subsidiary, G. & E. Bradley Ltd.) and the Collins Radio Co., of America.

MR. E. C. SHACKLETON, AssocI MechE, AssocIEE, has been appointed assistant chief project engineer of the Midlands Project Group of the Central Electricity Generating Board. After completing his training with the Stalybridge, Hyde, Mossley and Dukinfield Transport and Electricity Board, Mr. Shackleton continued to work for that organization from 1924 to 1947. He held a number of posts, eventually becoming technical and construction engineer in 1943. In 1947 he joined the Newport Corporation Electricity Department as a chief constructional engineer. The following year Mr. Shackleton was appointed senior generation construction engineer with the South Wales Division of the then British Electricity Authority and was promoted to generation engineer (construction) in the same division in January, 1952. In March, 1958, he became a project engineer in the Midlands Project Group.

DR. PETER FORTESCUE has been appointed chief research and development engineer of the newly organized General Atomic Europe. Dr. Fortescue, who is chief research and development engineer of General Atomic Division of General Dynamics Corporation in San Diego, California, will continue to act in that capacity. A British engineer who was formerly a deputy chief scientist at Harwell, Dr. Fortescue joined General Atomic in 1957 and served as senior member of the General Atomic team responsible for the High Temperature, Gas-cooled Reactor concept (HTGR).

Equipment and Materials

Items published in this monthly feature are compiled from manufacturers' current literature. Readers requiring further information should use the form at bottom of the page. Manufacturers are invited to send literature or details of their products for inclusion in this feature.

Surface Measurement

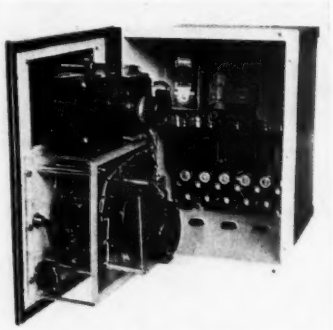
Recently released by Vision Engineering Ltd., is the "Optosurf" surface finish measuring instrument which provides a new approach to the problem of the measurement of surface finish. The instrument operates on a split field microscope principle which combines an illuminated and magnified image of the workpiece surface and the surface of one of a series of masters produced to British Standard Specification and mounted in an indexing turret. The chief advantages of this method are its complete portability, the fact that it can inspect, with the necessary attachments, bores down to $^1/_{16}$ in. diameter and up to

The components that make up the "Optosurf" surface finish measuring instrument made by Vision Engineering, Ltd.

80 ft in length, in addition to a complete range of external surfaces. Since no stylus or electronic equipment is employed, the instrument is free from the effects of vibration and it can be fitted direct to machine tools for checking *in situ*. The instrument, complete in fitted case, is priced at £95 and attachments include bench stand, probes, etc. **(AUG. 1)**

Multi-Point Scanners

West Instrument Ltd., of Brighton, the temperature control instrument manufacturers, have begun production of multi-point scanning equipment and are now completing a number of orders for customers in the nuclear energy, plastics and general engineering fields. The instrument is designed for the continuous monitoring of temperatures at up to 12 positions in succession. The temperature indication consists



Inside of the new multi-point scanning equipment built by West Instrument, Ltd.

of the standard West moving coil millivolt meter with a 5 in. scale, and sensing is by means of thermocouple or resistance bulb arrangement, according to the temperatures involved. Generally speaking, thermocouple sensing is effective above 200°C. and a resistance bulb is used below that temperature; but the methods of obtaining temperature readings are flexible and the West engineers will always examine the advantages of thermopile sensing at lower temperatures for particular applications. The instruments can be arranged for two types of action. A single, maximum temperature can be pre-set on the scale and, if the temperature at any of the scanned points reaches this, scanning stops and an alarm or trip action to shut down the machinery comes into operation. On the second arrangement, two temperatures can be set on the scale. If the temperatures scanned reach the lower point, a relay is operated and this provides the necessary contact for an alarm; then, if the temperature reaches the second, a trip action is brought into operation. There is provision for manual operation of the scanning cycle and also a visual indication of the temperature indicated at any given moment. The resistance bulb instrument is connected direct to mains supply without additional transformers, the mains being rectified and stabilized to give a d.c. source within the instrument. An example of the use to which this equipment is being put is in the proposed application to the generating gear of the Linear Particle Accelerator at Harwell. The power used is of such density that, if overheating of the bearings occurred, disintegration would rapidly follow.

(AUG. 2)

Teaching Machine

An automatic teaching machine which can instruct anyone on virtually any subject, ranging from bridge or golf to complex electronic problems or abstruse mathematical formulae was shown for the first time in the United Kingdom recently. Named the Auto-Tutor, the machine has been developed in the United States by U.S. Industries Inc. It is claimed to be the

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Please send further details of the following items in the EQUIPMENT and MATERIALS *feature for August, 1960*

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first machine to achieve the teaching function through integrated student participation. It is expected that initially its most useful role will be in large industrial and military training programmes. It is anticipated that the machine will be manufactured in the United Kingdom. The Auto-Tutor presents questions on any chosen subject to the student. If he answers correctly, the machine congratulates him and sets a further task. If the student is wrong, the machine tells him how and why and encourages him to tackle the problem again, after giving him further information. The Auto-Tutor can assess real knowledge and rate of progress so that the true educational level of the student is revealed. Advantages are that, treating the student as an intelligent human being, the tutor advances him at a rate determined by his own ability, frees the teacher for creative work, records progress of the trainee and provides a record of the individual's approach and reasoning process. **(AUG. 3)**

Continuous Measurement

Electronic Instruments Ltd., of Richmond, Surrey, market what they claim is the first instrument developed to measure continuously the fall-out of gamma radiation either indoors or out of doors. Called the "Gammagraph" it is powered by a car battery and is completely weatherproofed so that it can be used in isolated country areas without attention for at least a month. **(AUG. 4)**

Fall-out of gamma radiation is measured continuously by the Electronic Instruments, Ltd., "Gammagraph"

Bending Equipment

Chamberlain Industries Ltd., of London, E, manufacturers of the "Staffa" tube benders and hydraulic equipment, have reported the introduction of the "Staffa" Pedrick range of production bending machines. These have been manufactured in the U.S.A. for many years, and "Staffa" have been successful in making arrangements with the Pedrick Machine Tool Co., of Philadelphia to make them here in their own works under licence. They have an exceptionally smooth and fast operation and are suitable for bending pipe, tube, flats, rolled or extruded sections, and bar stock. A standard machine will bend pipe to a radius of three times the nominal bore, and tubes with wall thicknesses of 16 gauge or heavier, to a radius of three times the outside diameter. It will bend flat bars to a square corner, busbars edgewise to very small radii, and angles, channels and structural shapes within the power limits of each machine. Attractive, rugged and serviceable, it utilizes the compression method of bending, which consists of a rotary head with a stationary die and a rotating arm, which wipes the piece to be bent into the die. Mounted on a cast-iron or mild steel base, the table, driven from the bottom, is about 30 in. from the floor and consists of a large spur gear mounted on a roller bearing, buried in the table top under a guard to prevent dirt and swarf from damaging the bearings. Powered by a motor gear reduction unit, mounted under the table and controlled by a magnetic starter, push buttons enable the operator to start, stop and reverse the machine at will, whilst limit switches permit the machine, once started, to complete to the desired bend, reverse, and then return to the starting position and stop, without manual attention. The machines are designed with safety as a paramount feature, and provide "foolproof" operation as long as the limit switches are not removed. In addition, they are so designed that even unskilled labour can operate them rapidly and efficiently. This ensures an appreciable saving in the direct labour operating costs. **(AUG. 5)**

Rotary Glove Box

A new glass fibre rotary glove box incorporating many advanced design features and claimed to be the first of its type produced in the United Kingdom has been introduced by Seton Creaghe Engineering Ltd. Specially designed for handling radioactive and other toxic materials, the new "Secray" Mk. III glove box is also suitable for the assembly of small components under stringent dust-free conditions. In the design, high corrosion resistance has been achieved and leakage rate reduced to a minimum by moulding the box in a polyester resin glass fibre laminate. A considerable weight reduction has also been obtained over the more conventional steel glove boxes with corresponding benefits in manhandling the equipment. In the standard model, two 6 in. glove ports are provided in the main window giving access to an illuminated rotating table, and an 8 in. bag port is incorporated on the right-hand side for passing components into the box. Additional glove and window ports can be provided to suit customers' requirements. Fitted at the centre of the dome-shaped roof

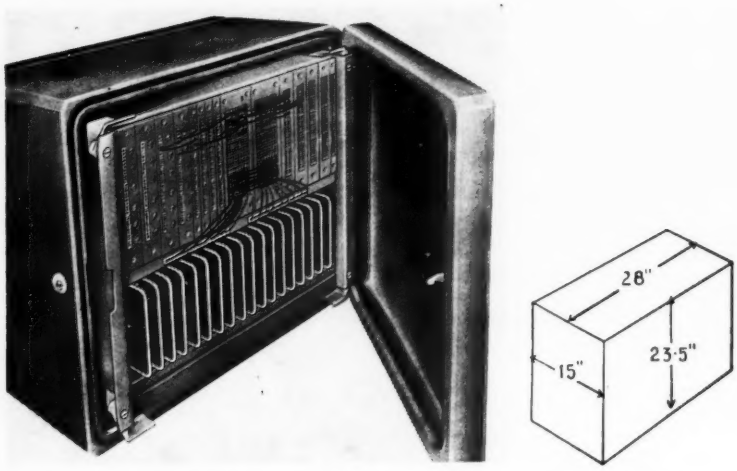
A new glass fibre rotary glove box introduced by Seton Creaghe Engineering, Ltd.

is a 6 in. explosion port which is sealed by a rubber ball; when the box is pressurized above 1 in.wg the ball lifts thereby releasing the pressure. A bag ring is provided enabling the released gases to be evacuated via the laboratory extract system. A standard Vokes extract filter, with a specially designed quick release clamp for easy one handed operation, is contained inside the glove box. The partial vacuum of 4 in. water-gauge is maintained by means of an air suction ejector or vacuum pump connected to the outside of the box. The moulded box is mounted on a tubular stand fitted with casters incorporating braking facilities and variations of up to 6 in. in the height of the box can be obtained by means of screw jacks. A turntable is contained inside the box. The turntable, which has been arranged to lift clear of the floor of the main box for easy decontamination purposes, can be locked in any position by a footbrake and in order to avoid undue torsion on the service leads, it can be turned through one revolution only. A sector has been cut out of the turntable so that access can be gained by the operator to the centrifuge port, the trunking port and trash port. These ports are located in the floor of the main box, and each is fitted with snap closure lids and O-ring buffer seals. Connection to other boxes, when necessary, is made by means of glass fibre trunking and transport of radio-active material is effected by conveyor belt. The dimensions of the Secray Mark III rotary glove box are:—overall height 6 ft 8 in., overall diameter 4 ft 3 in., height of box 3 ft 8 in. Weight is 600 lb. Price of the standard model is

approximately £700 and delivery is about three months from order. **(AUG. 6)**

Low-cost Computer

"Anatrol" is the name of a low cost analogue computer introduced by the System Engineering Group of De Havilland Propellers Ltd., at the recent IEA Exhibition. It has been developed for on-line process control and it represents a completely new approach to the design of analogue computers for this purpose. The computing accuracy of "Anatrol" is compatible with present-day measurement accuracies, allowing it to be easily and efficiently integrated into existing control systems. It also has a computing potential equal to a very much more costly and complex computer system. Conventional analogue computers provide solutions to process equations at speeds which are extremely fast when compared with process dynamics. This fact, coupled with the need to increase reliability and to reduce price considerably led to the choice of the principles used in "Anatrol." Here the minimum of computing amplifiers and multipliers are formed into an arithmetic unit. This unit is then used to provide a step by step solution of the equations, according to a pre-set programme in which each step is selected sequentially by a switch system. Short stores are used to retain information on the result of a step in the solution, this data being used in a later stage of the computation. Long stores are used to clamp the outputs at the last computed figure while fresh values are being determined. Up to a maximum of 25 steps is available, which gives the computer the potential of a machine employing at least 75 computing amplifiers and 25 multipliers, with the exception of some electro-mechanical switching elements. The machine makes use of module construction, and different component-unit combinations may be used according to the problem. The computer is 23.5 in. high, 28 in. wide and 15 in. deep. It weighs 180 lb. **(AUG. 7)**



De Havilland Propellers, Ltd., make this compact handsome low-cost computer

BOOK REVIEWS

Effects of Nuclear Radiation on Men and Materials, by Dr. T. G. Helvey. Published by John F. Rider Publisher Inc., New York; Chapman & Hall Ltd., London. Size 5½ in. × 9 in. × 56 pp. Price 15*s.* 0*d.*

The aim of this book is to introduce designers of nuclear powered aircraft and rockets to the problems of radiation. Up to a point it does this admirably—the descriptions of radiation and the different nuclear particles are lucid and clearly illustrated, as are the chapters on the effects of radiation on men and materials. What is disappointing is that when the author reaches the section dealing with the protection to be afforded crews of nuclear propelled aircraft and space vehicles he barely scrapes the surface of the subject and the reader finishes the book with only his appetite whetted. This is not to say the book is not useful—indeed for anybody not versed in the mysteries of nuclear radiation it does a useful job. But why truck it up in handsome stiff covers and aim in such an elementary way to aircraft designers when something less expensive would have been equally adequate and at the same time command a wider readership, particularly among laymen?

T.R.

Atoms in Action, by J. E. Radford and G. E. Speck. Published by Ward Lock & Co., Ltd. Size 8 in. × 4 in. × 128 pp. Price 10*s.* 6*d.*

One of the *Marvels of Modern Discovery* series of Ward Lock books, this is aimed at the layman. It makes very easy and interesting reading, though at times is exasperating. As when, for instance, it refers to a diagram which is not in the place position stated and when sometimes the authors become so involved as to make more than one re-reading necessary. Some of the major problems that have to be overcome are adequately dealt with, particularly those related to the creep of metals and radiation. One of the most fascinating parts of the book is description of the nuclear work undertaken in medicine and agriculture. The book ends with a useful glossary of terms used in nuclear physics.

Science, edited by panel. Published by Macdonald & Co. (Publishers), Ltd. 11 in. × 8 in. × 367 pp. Price 45*s.*

This is a very general and on the whole elementary book which has the unfortunate listing of exciting work told in some parts in a dull manner. It nevertheless is a worthwhile work for it will capture the mind of the youngster with the exciting illustrations and its digging down into the history of science, and will urge him on to the more specialized fields covered by this book. Cleopatra (not the Queen) who had a recipe for turning base metal to gold would be intrigued by the fact that this can now be done; by bombarding an atom of mercury (80 protons) with neutrons it is turned into an atom of gold (79 protons). This was first achieved by Kenneth T. Bainbridge in 1941. Unfortunately this is a much more expensive way of getting gold than the natural methods. This is a book for your library or a suitable gift for a young student.

Monographs Received

Equilibrium Configuration of a Toroidal Gas Discharge—2—Configurations with Almost Separated Fields, by K. J. Whiteman. Published by UKAEA. Reference AERE—R3135. Available from H.M. Stationery Office. Price 4*s.* 6*d.*

A Programme for the Calculation of the Doppler Broadened Resonance Absorption of Neutrons which are Scattered in Thick Targets (Mercury Autocode Programme No. 17: Scattering Integrals), by I. C. Pyle. Published by UKAEA. Reference AERE—R 3228. Available from H. M. Stationery Office. Price 3*s.* 6*d.*

Geiger Gas Counting Methods of Assaying Tritiated Hydrogen and Tritiated Water, by J. F. Cameron and B. J. Puckett. Published by UKAEA, Reference AERE—R3092. Available from H. M. Stationery Office. Price 4*s.* 0*d.*

A Method of Sealing Lithium Fluoride Windows to Pyrex Vacuum Systems, by P. C. Wildy. Published by UKAEA. Reference AERE—R3201. Available from H.M. Stationery Office. Price. 1*s.* 2*d.*

The Operation of Borehole Logging Equipment in Boreholes Containing Saline Solutions, by D. Williams and H. A. G. Cole. Published by UKAEA. Reference AERE—R 3196. Available from H.M. Stationery Office. Price 3*s.* 0*d.*

A Vehicle Mounted Scintillation Ratemeter for Environmental Safety, by I. W. Cavell. Published by UKAEA. Reference AEEW—M 29. Details from Winfrith Secretariat, Atomic Energy Establishment, Winfrith, Dorchester, Dorset.

Simulator for Reactor School

GENERAL Precision Systems Ltd., the makers of the famous "Link" and other aircraft trainers, have built for the use of the Harwell Reactor School a reactor simulator designed to the school's own specifications. It is an analogue computer which represents the performance of a nuclear reactor in the form of d.c. voltages the range of power simulated being from $^1/_{10}$w to 1,000 MW.

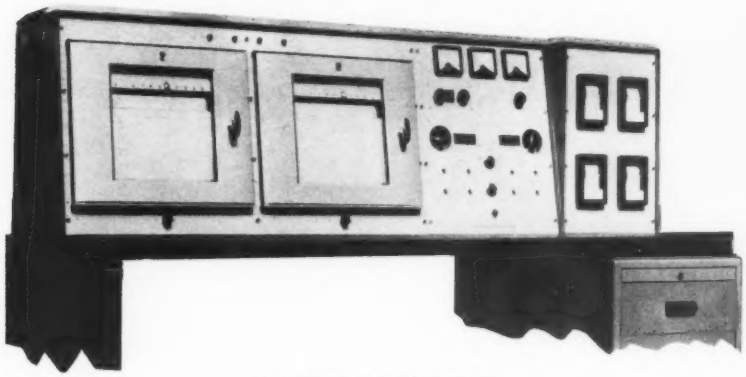
A novel feature of the equipment is that the power range is covered without a break over the 10 decades and with equal sensitivity in each decade. Accuracy is therefore constant at high and low powers. This is achieved by the computer transposing the reactor kinetic equations into logarithmic form and then making the computations in this form.

The simulator is operated from a control console which is typical in design of those used in reactor installations. The computer is housed in a standard 19 in. rack which is linked with the console by a group of flexible cables.

Controls in Three Parts

In using the reactor the instructor pre-sets the characteristics of the simulated reactor and then sets the students specific problems of control to be solved by the operation of the controls and instruments on the console. As these controls are typical of what the students will later meet in practice they not only learn about the reactor kinetics but they also become familiar with types of control and indicator.

The control console is divided into three principal sections. On the left the two moving charts which indicate power output linearly and logarithmically. Above them are temperature, doubling time and low and high power trips. Below are switches used to obtain the range of simulated power from $^1/_{10}$w to 1,000 MW.



Control panel of the Simulator

The central panel of the console contains instruments for measuring power level, doubling time and coolant flow and controls for moving the reactor control rods either up or down and either quickly or slowly. There is one set for coarse positioning of the rods and another for fine positioning.

Clock face dials, in addition to numerical gauges, are used to indicate the position of the rods. There are also scram and reset trips in this part of the panel.

The third section is taken up with temperature charts indicating coolant inlet and outlet heat and the temperatures of the fuel and of the moderator.

Pre-set controls are attached to the computer rack and are fitted with a lockable cover so as to prevent them from being altered without the knowledge of the instructor.

TRADE LITERATURE

It is difficult not to be impressed with the vast scope of the work done by G. Irwin & Partners, Ltd., as described in their new spiral bound booklet. The many photographs alone speak for themselves, and will doubtless prove an efficient advertisement.

Ardente Acoustic Laboratories, Ltd., have produced a useful catalogue of their range of miniature electronic components. Following a brief introduction to the Ardente laboratories, and the use of miniaturization, there are details of the products illustrated with diagrams and photographs. This booklet is obviously intended for reference and contains a pocket at the back to hold future supplementary leaflets.

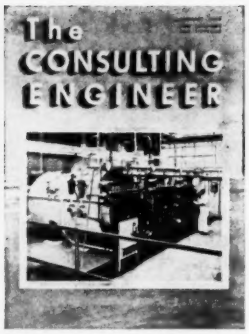
General Electric, U.S.A., use 21 compelling pen and ink drawings to illustrate their **"5 Years of Commercial Atomic Progress."** The small amount of written description is concise and contains only essential facts and figures, but provides a dramatic, if scanty, background to the scope of G.E.'s work in this field.

"The Raw Materials of Progress," by Laporte Industries, Ltd.—Here is a booklet which could interest anybody in chemicals and at the same time is an example of first-class publicity. The booklet comprises exciting photographs, extremely readable narrative and fascinating pen drawings. The introduction is more than a description of the founding of Laporte; it is a description of the beginnings of the chemical industry in the early 20th century. The middle section contains chapters on the main Laporte chemicals from hydrogen peroxide to fuller's earth, and the last section, entitled "The Future," leaves the reader in no doubt about the soundness of this company's ideas. The book has been issued to shareholders and the group's major customers, and in house magazine form to the company's employees.

In the new catalogue published by Electrothermal Engineering, Ltd., of special interest are the flexible furnaces and assorted kinds of heating mantles, a very far cry from the gas bunsens used in laboratories not so many years ago. In fact, many kinds of modern heating equipment for use in laboratories are introduced and illustrated.

Under the title of **"Tomorrow's Metals Today,"** ICI have brought up to date the notes they issued last year at the opening of their beryllium plant at Birmingham. They explain the processes used in refining the so-called new metals, titanium, zirconium and beryllium, and then detail properties and applications. Also described briefly are the present activities of their research department on the metals hafnium, niobium and vanadium. Also from ICI is the fifth of a series of data booklets on titanium. It lists weights of the metal in various forms.

Complete technical details of the new 15-ton capacity Rapier 1520 mobile crane comprise a booklet issued by Ransomes & Rapier, Ltd. There are useful operating diagrams and radii tables together with adequate photographs of the crane in action.



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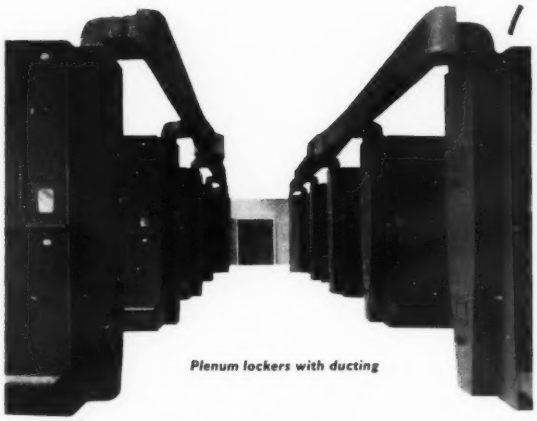

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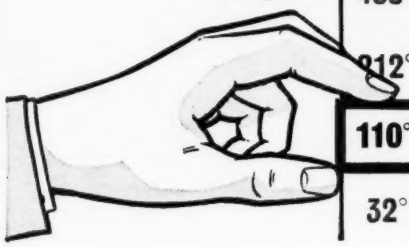
Illustration shows Isotapes (before application of lagging) as installed by Babcock & Wilcox Ltd., at the Generating Station of the C.E.G.B. at Plymouth.

Write for latest catalogues on surface heating units.



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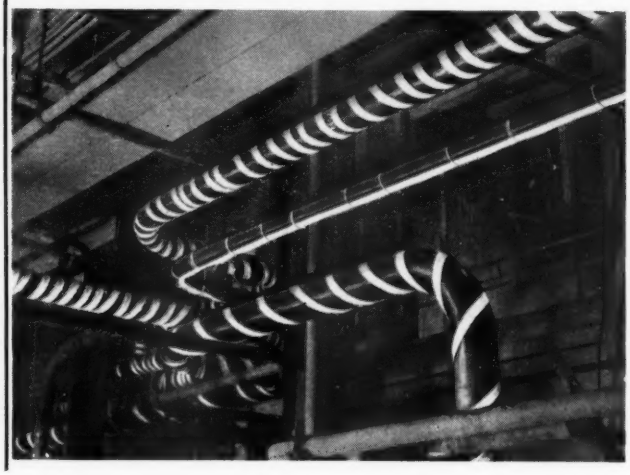

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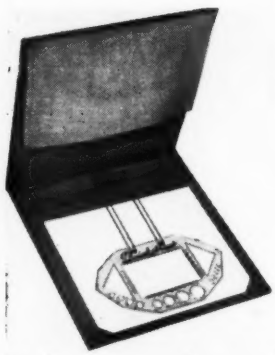

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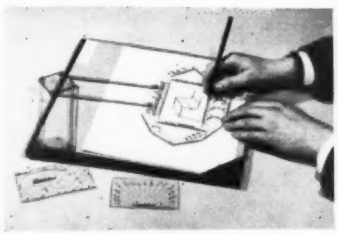

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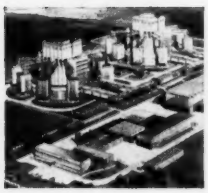

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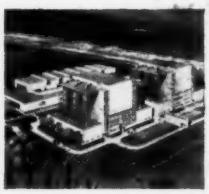

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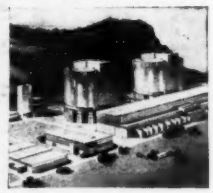

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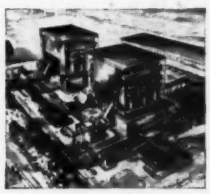

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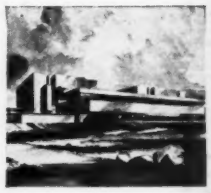

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